Nuclear Effects in Electron & Neutrino DIS

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Outline

- Experimental evidence of nuclear effects in parton distributions/structure functions. (charged-lepton DIS and hadronic Drell–Yan reactions).
- The development of a realistic model of nuclear structure functions. Phenomenology of nuclear DIS.
- Results for neutrino-nuclear structure functions.

Experimental evidence of nuclear effects in DIS

- Data on nuclear effects in DIS are available in the form of the ratio $\mathcal{R}_2(A/B) = F_2^A/F_2^B$.

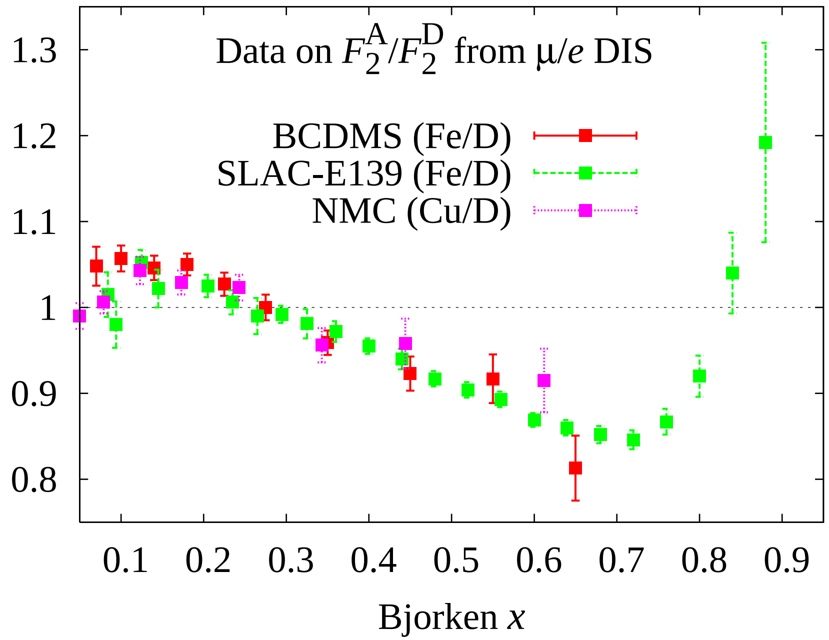
- Targets:
  Variaty of nuclear targets from ^{2}D to ^{208}Pb

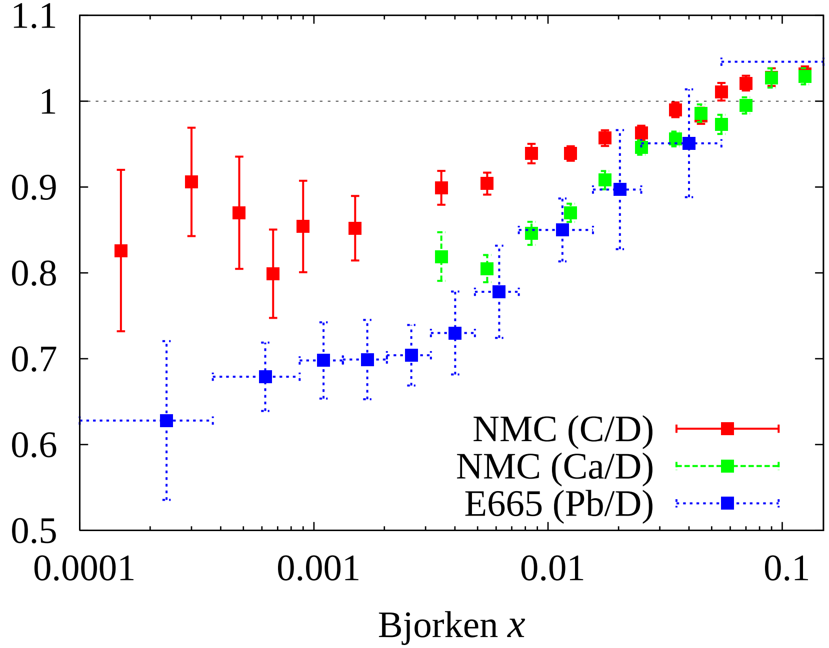
- Experiments:
  – Muon beam at CERN (EMC, BCDMS, NMC) and FNAL (E665).
  – Electron beam at SLAC (E139, E140), HERA (HERMES) and recently at JLab.

- Kinematics and statistics:
  Data covers the region $10^{-4} < x < 0.9$ and $0 < Q^2 < 150\,\mathrm{GeV}^2$. About 600 data points with $Q^2 > 1\ \mathrm{GeV}^2$.

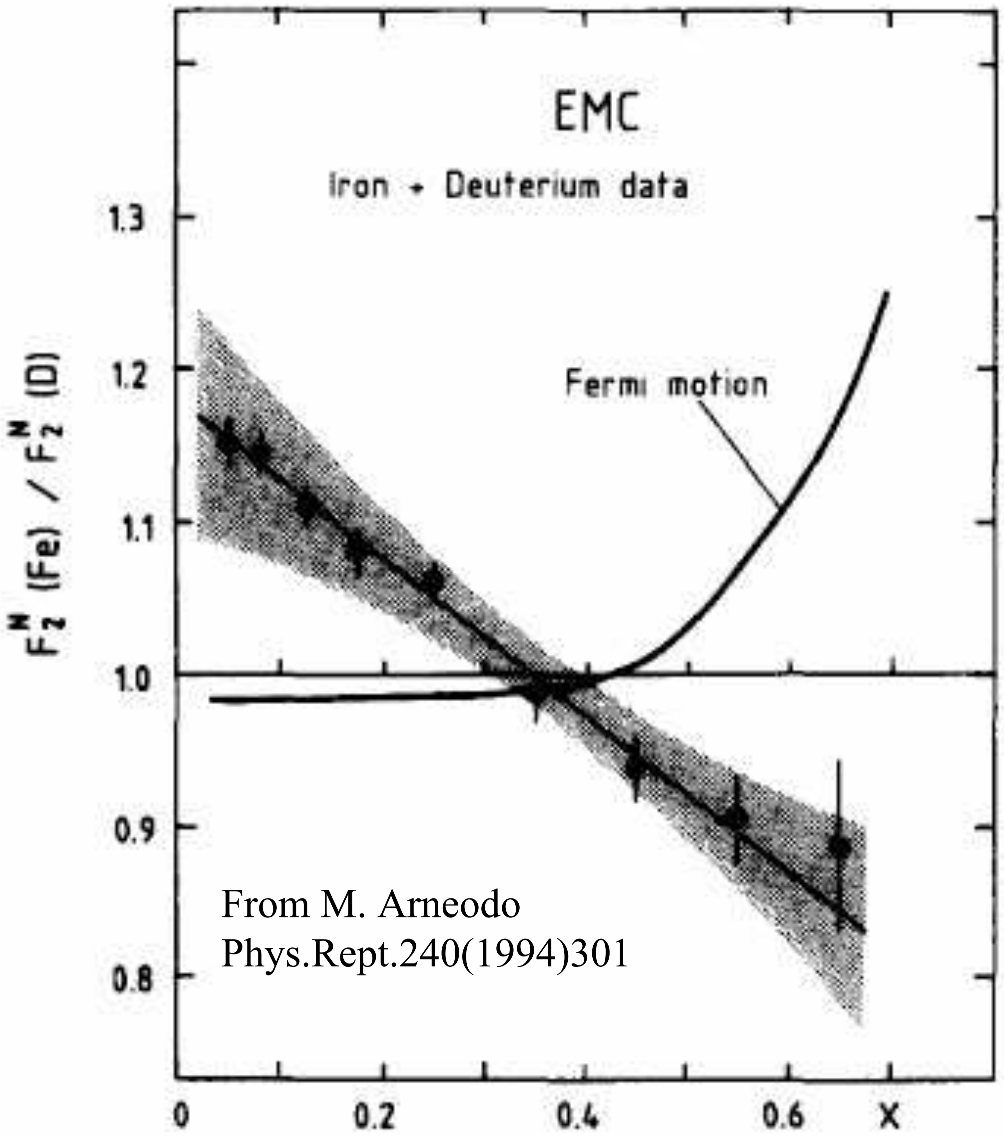
Data on the EMC ratios show a weak Q^2 dependence that suggests scaling origin of (at least a part of) nuclear effects. Characteristic nuclear effects were observed for different kinematical regions of the Bjorken x.

- Nuclear shadowing at small values of x ($x < 0.05$).
- Antishadowing at $0.1 < x < 0.25$.
- A well with a minimum at $x \sim 0.6 \div 0.75$ (EMC effect).
- Enhancement at large $x > 0.75 \div 0.8$ (Fermi motion region).



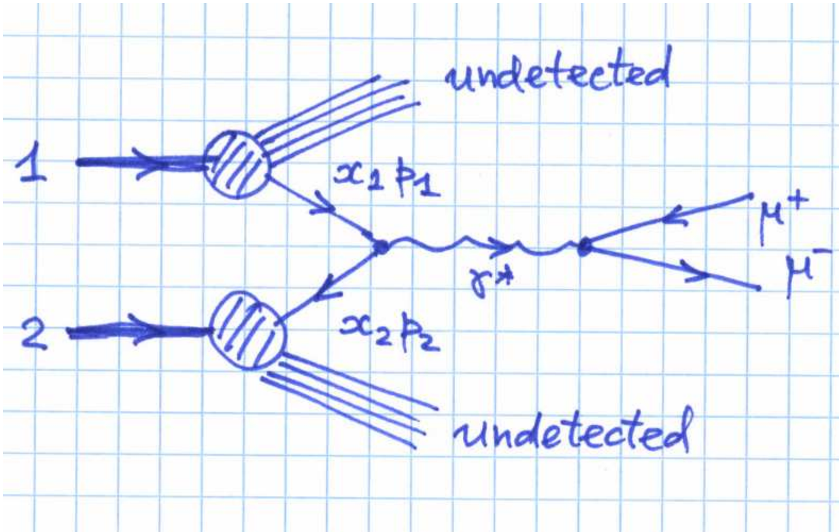


Original observation by European Muon Collaboration



Drell-Yan reaction

Drell-Yan production of lepton pairs in hadron collisions $B + T \to \mu^+\mu^- +$ anything



$$
\begin{aligned}
\frac{\mathrm{d}^2\sigma}{\mathrm{d}x_B \mathrm{d}x_T} =& \frac{4\pi\alpha^2}{9Q^2} K \sum_a e_a^2 \big[q_a^B(x_B)\bar{q}_a^T(x_T) \\
& + \bar{q}_a^B(x_B) q_a^T(x_T) \big] \\
x_T x_B =& Q^2/s, \\
x_B - x_T =& 2q_L/\sqrt{s} = x_F
\end{aligned}
$$

Q^2 is invariant mass squared of the lepton pair, q_L the longitudinal momentum of the lepton pair, s the center-of-mass energy squared. Selecting small Q^2/s and large x_F we probe the target's sea.

E772 data on the ratio of Drell–Yan yields

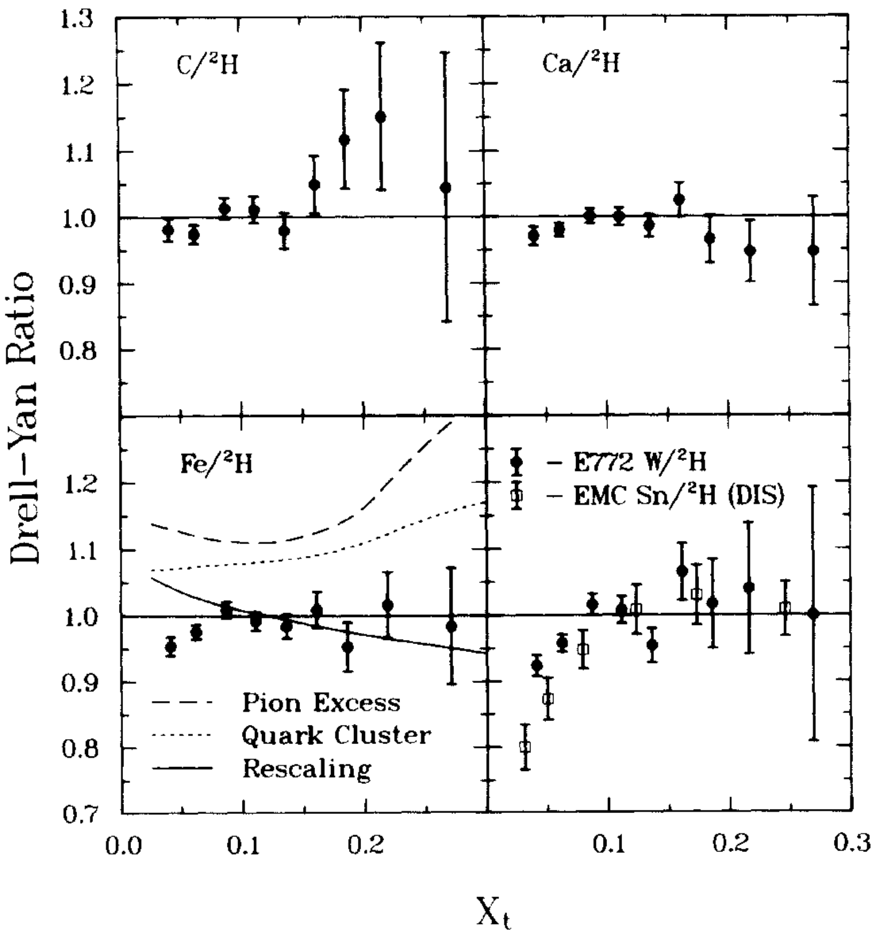


FIG. 3. Ratios of the Drell-Yan dimuon yield per nucleon, $Y_A/Y_{^2\mathrm{H}}$, for positive x_F. The curves shown for Fe/^{2}H are predictions of various models of the EMC effect. Also shown are the DIS data for Sn/^{2}H from the EMC (Ref. 4).

In E772 experiment $s = 1600\,\mathrm{GeV}^2$. At $x_F = x_B - x_T > 0.2$ the process is dominated by $q^B\bar{q}^T$ annihillation. The ratio of DY yields for different targets is proportional to the ratio of antiquark distributions:

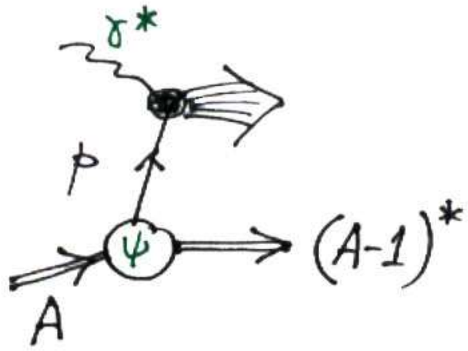
$$\frac{\sigma_A^{\mathrm{DY}}}{\sigma_B^{\mathrm{DY}}} \approx \frac{\bar{q}_A(x_T)}{\bar{q}_B(x_T)}$$

Description of nuclear DIS in Impulse approximation

Fermi motion and nuclear binding corrections (FMB)

$$F_2^A(x,Q^2) = \int \mathrm{d}^4p\, \mathcal{P}_A(p) \left(1+\frac{p_z}{M}\right) F_2^N(x',Q^2,p^2),$$

$$x = \frac{Q^2}{2p\cdot q}, \quad x' = \frac{Q^2}{2p\cdot q} = \frac{x}{1+(\varepsilon+k_z)/M}$$

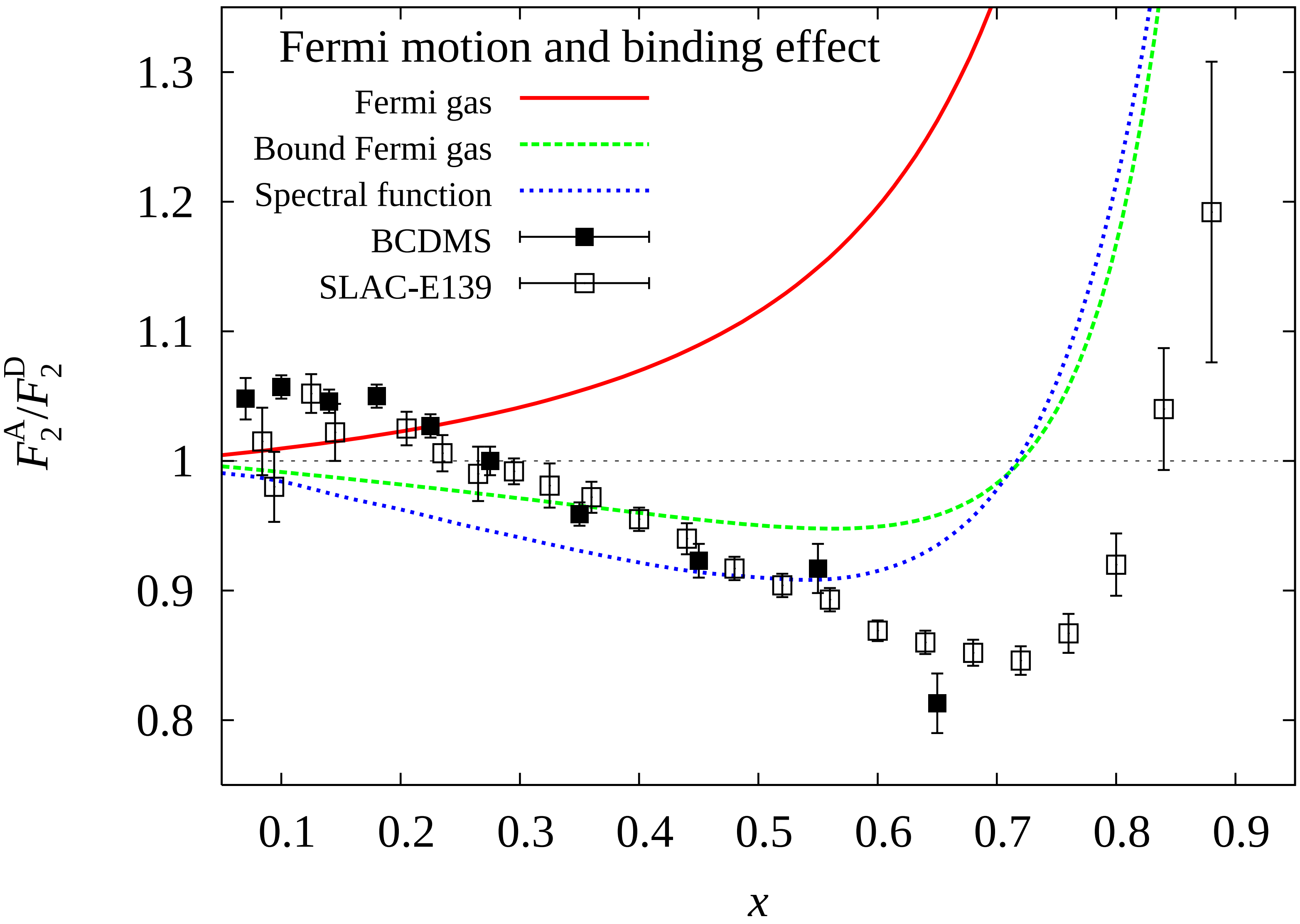


Similar equations hold in impulse approx. for other structure functions (F_T, F_3). Fermi motion and binding effect is driven by nuclear spectral function

$$\mathcal{P}_A(p) = \sum_n |\psi_n(\boldsymbol{p})|^2 \delta(\varepsilon + E_n(A-1,-\boldsymbol{p}) - E_0(A)).$$

Spectral function describes probability to find a bound nucleon with momentum $\boldsymbol{p}$ and energy $p_0 = M + \varepsilon$.

EMC Ratio and FMB correction



Nucleon off-shell effect

Bound nucleons are off-mass-shell $p^2 = (M+\varepsilon)^2 - \boldsymbol{p}^2 < M^2$. In off-shell region nucleon structure functions depend on additional variable p^2.

The virtuality parameter $v = (p^2 - M^2)/M^2$ is small on average (e.g. for ^{56}Fe $\langle v \rangle \sim -0.15$). Hence a linear approximation in v

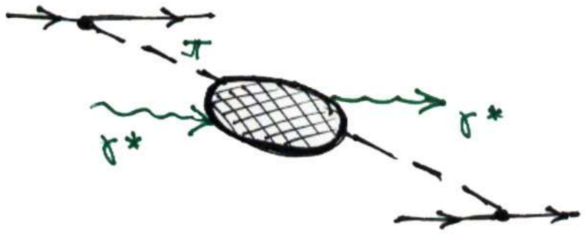
$$F_2^N(x, Q^2, p^2) = F_2^N(x, Q^2)\big[1 + v\,\delta f(x)\big]$$

We follow a phenomenological approach and extract the off-shell function $\delta f(x)$ from data on the nuclear structure functions [S.K. & R.Petti, NPA765(2006)126].

Nuclear pion effect

Leptons can interact with nuclear meson field which mediate interaction between bound nucleons. This process generate a pion correction to nuclear structure functions.

$$\delta F_i^{\pi/A}(x,Q^2) = \int_x \mathrm{d}y f_{\pi/A}(y) F_i^{\pi}(x/y, Q^2)$$



- Contribution from nuclear pions (mesons) is important to balance nuclear light-cone momentum $\langle y \rangle_\pi + \langle y \rangle_N = 1$.

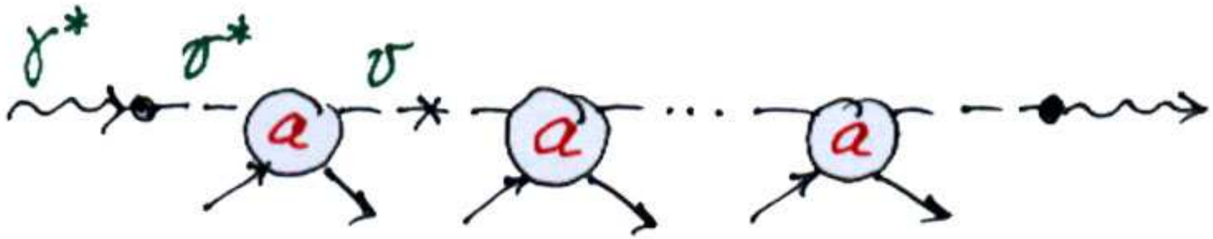
- The nuclear pion distribution function is localized in a region of $y < p_F/M \sim 0.3$. For this reason the pion correction to nuclear (anti)quark distributions is localized at $x < 0.3$.

- The magnitude of the correction is driven by average number of "pions" $n_\pi = \int \mathrm{d}y\, f_{\pi/A}(y)$. By order of magnitude $n_\pi/A \sim 0.1$ for a heavy nucleus like ^{56}Fe.

- Nuclear pion correction effectively leads to enhancement of nuclear sea quark distribution and does not affect the valence quark distribution (for isoscalar nuclear target).

Nuclear DIS in coherent regime: shadowing

At small x DIS is driven by $\gamma^* \to v^*$ conversions into virtual hadronic states. The nuclear correction at small x comes from multiple interactions of hadronic component of virtual photon during the propagation through matter.



The series can be summed up in a compact form in optical approximation (suitable for large A)

$$\delta\mathcal{R} = \frac{\delta_{\rm coh} F_T}{F_T^N} \approx \frac{\delta_{\rm coh}\sigma_T}{\sigma_T} = \operatorname{Im}\left(i a^2 \mathcal{C}_2^A(a)\right) / \operatorname{Im} a,$$

$$\mathcal{C}_2^A(a) = \int_{z_1<z_2} \mathrm{d}^2\boldsymbol{b}\, \mathrm{d}z_1 \mathrm{d}z_2\, \rho_A(\boldsymbol{b}, z_1)\rho_A(\boldsymbol{b}, z_2) \exp\left[i \int_{z_1}^{z_2} \mathrm{d}z' \left(a\, \rho_A(\boldsymbol{b}, z') - k_L\right)\right].$$

$a = \sigma(i + \alpha)/2$ is (effective) scattering amplitude in forward direction ($\alpha = \operatorname{Re} a / \operatorname{Im} a$), $k_L = Mx(1 + m_v^2/Q^2)$ is longitudinal momentum transfer in the process $v^* \to v$, which accounts for finite life time of intermediate hadronic state. The presence of k_L suppresses coherent nuclear effect at large x.

Nuclear shadowing

Dependence on C-parity and isospin

The amplitude a_h^I describes interaction of hadronic component of the virtual boson with a nucleon. This amplitude is characterized by helicity state h of the boson ($h = \pm 1$ for transverse polarization and $h = 0$ for longitudinal polariz.) and by isospin I (amplitude is different for proton and neutron).
Average transverse amplitude $a_T^I = (a_{+1}^I + a_{-1}^I)/2$
Helicity asymmetry $a_\Delta^I = (a_{+1}^I - a_{-1}^I)/2$

Correspondence with structure functions:

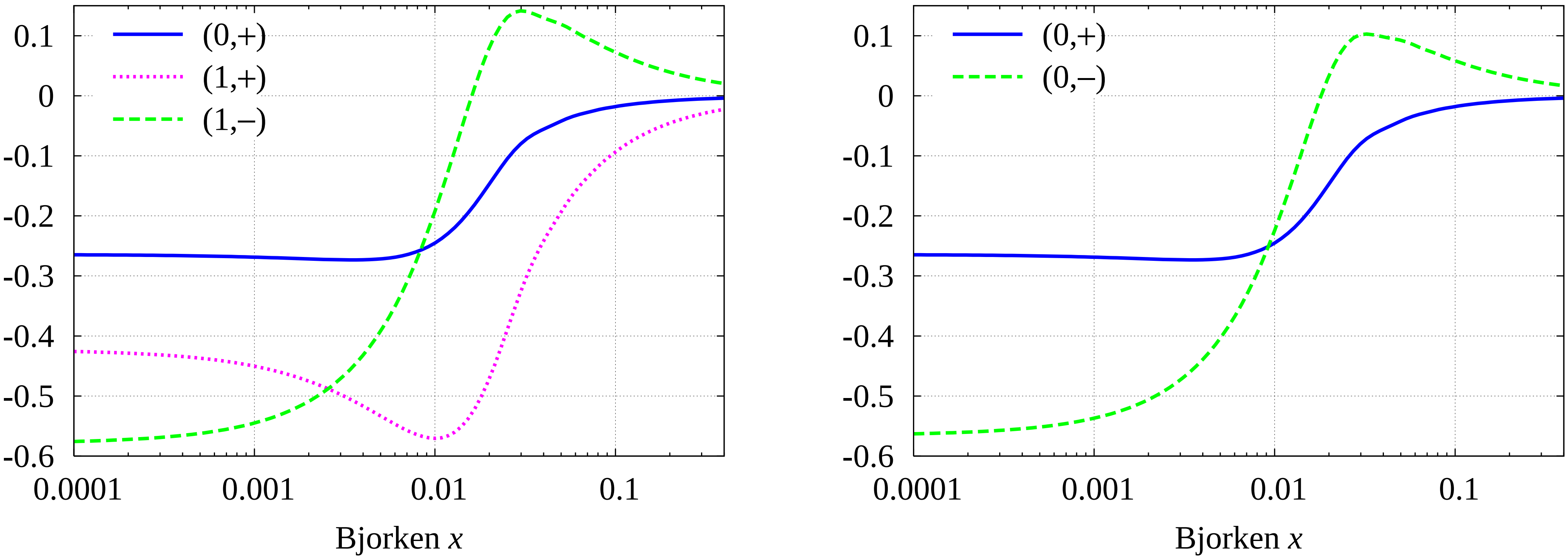
$$
\begin{aligned}
a_T^0 &\longrightarrow F_T^{\nu+\bar\nu} & \qquad a_\Delta^0 &\longrightarrow F_3^{\nu+\bar\nu} \\
a_T^1 &\longrightarrow F_T^{\nu-\bar\nu} & \qquad a_\Delta^1 &\longrightarrow F_3^{\nu-\bar\nu}
\end{aligned}
$$

Coherent nuclear effects are not universal but depend on the type of the structure function. Nuclear corrections to C-even F_T (or $q + \bar q$) and C-odd F_3 (or $q - \bar q$) are given by

$$
\delta\mathcal{R}^{(0,+)} = \mathrm{Im}\left[i a_T^2 \mathcal{C}_2^A(a_T) \right] / \,\mathrm{Im}\, a_T,
$$

$$
\delta\mathcal{R}^{(0,-)} = \mathrm{Im}\left[i a_\Delta \tfrac{\partial}{\partial a_T} \left(a_T^2 \mathcal{C}_2^A(a_T) \right) \right] / \,\mathrm{Im}\, a_\Delta = \mathrm{Im}\left[i(i+\alpha_\Delta) \tfrac{\partial}{\partial a_T} \left(\cdots \right) \right]
$$

Note that C-odd correction $\delta\mathcal{R}^{(0,-)}$ depends on $\alpha_\Delta = \mathrm{Re}\, a_\Delta / \,\mathrm{Im}\, a_\Delta$ but not on the corresponding cross section and the strength of nuclear corrections is driven by σ_T, the cross section in the C-even channel.



The ratio $\delta\mathcal{R}^{(I,C)}$ calculated for different isospin and C-parity scattering states for ^{207}Pb at $Q^2 = 1\,\mathrm{GeV}^2$. The labels on the curves mark the values of the isospin I and C-parity, (I,C).

Phenomenology of nuclear DIS

The idea and motivation:

- Take into account major nuclear corrections and build a quantitative model for nuclear structure functions (for more detail see S.K. & R.Petti, NPA765(2006)126)

$$F_i^A = F_i^{p/A} + F_i^{n/A} + \delta_\pi F_i^A + \delta_{\text{coh}} F_i^A$$

- Parameterize off-shell correction function $\delta f(x)$ and effective scattering amplitude a_T responsible for nuclear shadowing

- Calculate nuclear structure functions, test with data and extract parameters from data.

- Verify the model by comparing the calculations with data not used in analysis as well as with the constraints due to normalizations and the sum rules.

Hadronic/nuclear input to the model

- Proton and neutron SFs computed in NNLO pQCD + TMC + HT using phenomenological PDFs and HTs from fits to DIS data (Alekhin).
- Realistic two-component nuclear spectral function (mean-field + correlated part) is used to calculate SF in impulse approximation.
- Mesonic correction is calculated using pion PDFs extracted from fits to Drell–Yan data.
- Coherent nuclear corrections are calculated using multiple scattering theory and nuclear number densities $\rho_A(\boldsymbol{r})$ from elastic electron scattering data.

Analysis

We use the data from electron and muon DIS in the form of ratios $\mathcal{R}_2(A/B) = F_2^A/F_2^B$ for a variaty of targets. The data are available for A/D and $A/^{12}$C ratios.

We perform a fit to minimize $\chi^2 = \sum_{\text{data}} (\mathcal{R}_2^{exp} - \mathcal{R}_2^{th})^2/\sigma^2(\mathcal{R}_2^{exp})$ with σ the experimental uncertainty. In the fit we use data with $Q^2 > 1\ \mathrm{GeV}^2$ (overall about 560 points). Then we validate the predictions for $Q^2 < 1\ \mathrm{GeV}^2$.

We use the parametrization $\delta f_2(x) = C_N(x - x_1)(x - x_0)(h - x)$ for the off-shell function. For the effective scattering amplitude of hadronic component of γ^* off the nucleon we use the following model

$$\bar{a}_T = \bar{\sigma}_T(i + \alpha)/2,$$

$$\bar{\sigma}_T = \sigma_1 + \frac{\sigma_0 - \sigma_1}{1 + Q^2/Q_0^2}$$

Preliminary trials: Initialy the parameters $\sigma_1,\ \sigma_0,\ \alpha_T,\ Q_0^2$ and $x_1,\ x_0,\ h,\ C_N$ are free and we study the correlations between them.

$*$ The parameter h turned out fully correlated with x_0, $h = 1 + x_0$ fixed in the final fit.

$*$ Best fit gives $\sigma_1 \approx 0$. The correlations between σ_1 and off-shell parameters are negligible. We fix $\sigma_1 = 0$.

$*$ The parameter σ_0 is strongly correlated $\sigma_0 \leftrightarrow Q_0^2$, $\sigma_0 \leftrightarrow \alpha_T$. Best fit gives $\alpha_T = -0.179 \pm 0.038$ and $\Delta\chi^2 \sim 29$ compared to the fit with $\alpha_T = 0$. If we fix $\sigma_0 = 27\,\text{mb}$ (average cross section in the VMD model) then $\alpha_T = -0.182 \pm 0.037$. This is in good agreement with results on the analysis of ρ^0 meson production in VMD. In final fit we fix $\sigma_0 = 27\,\text{mb}$ and $\alpha = -0.2$.

The ajustable parameters of the model are $x_0,\ x_1,\ C_N$ and Q_0^2. Additional constraint of the fit is the normalization of nuclear valence quark number. This allows us to constrain x_1. For this purpose we use an iterative algorithm:

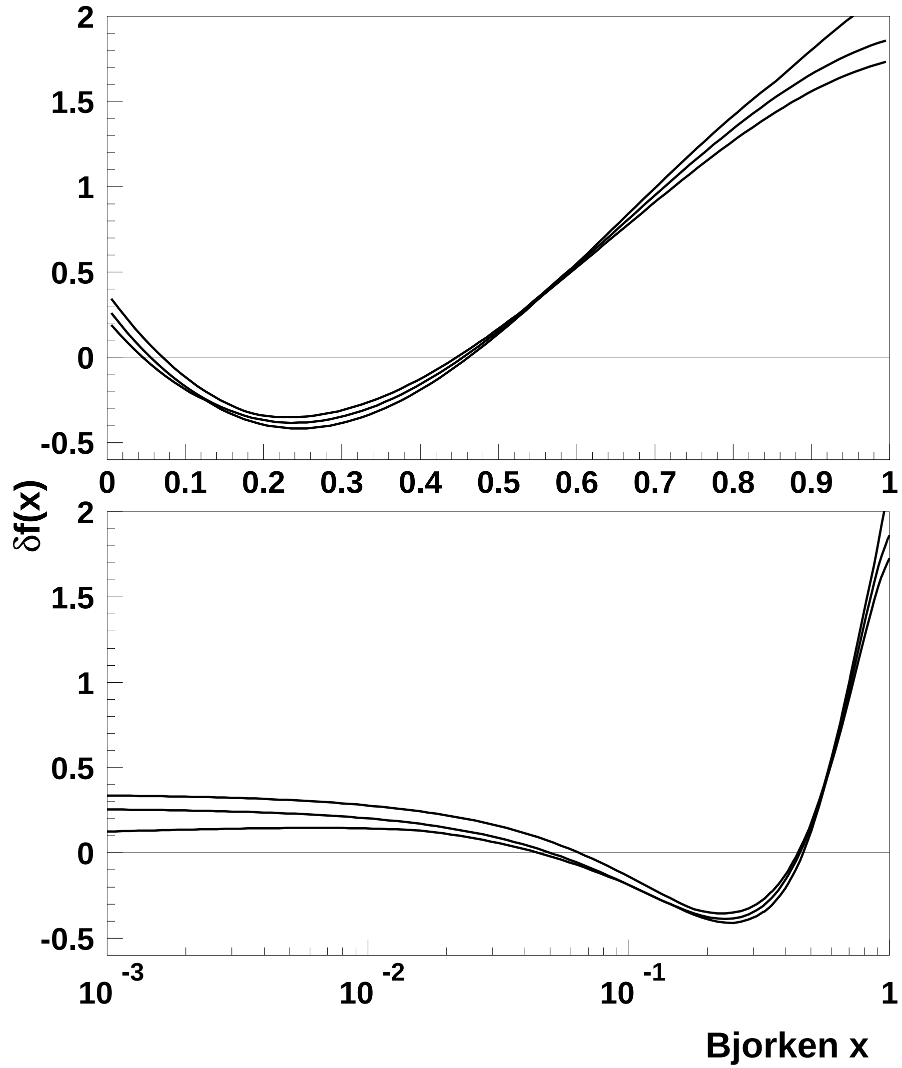
1. Fit with fixed x_1 without normalization constraint.
2. Calculate $\delta N_{\rm val} = \delta N_{\rm val}^{\rm off-shell} + \delta N_{\rm val}^{\rm shadowing}$ as a function of Q^2 at $Q^2 > 5\,\mathrm{GeV}^2$
3. Change x_1 and go to 1. until $|\delta N_{\rm val}|$ is minimized provided that χ^2 is still "acceptable".

Off-shell function

The function $\delta f(x)$ provides a measure of modification of quark distributions in bound nucleon.

$$\begin{aligned}\delta f(x) &= C_N(x-x_1)(x-x_0)(1+x_0-x)\\ C_N &= 8.1 \pm 0.3 \pm 0.5\\ x_0 &= 0.448 \pm 0.005 \pm 0.007\\ x_1 &= 0.05\end{aligned}$$

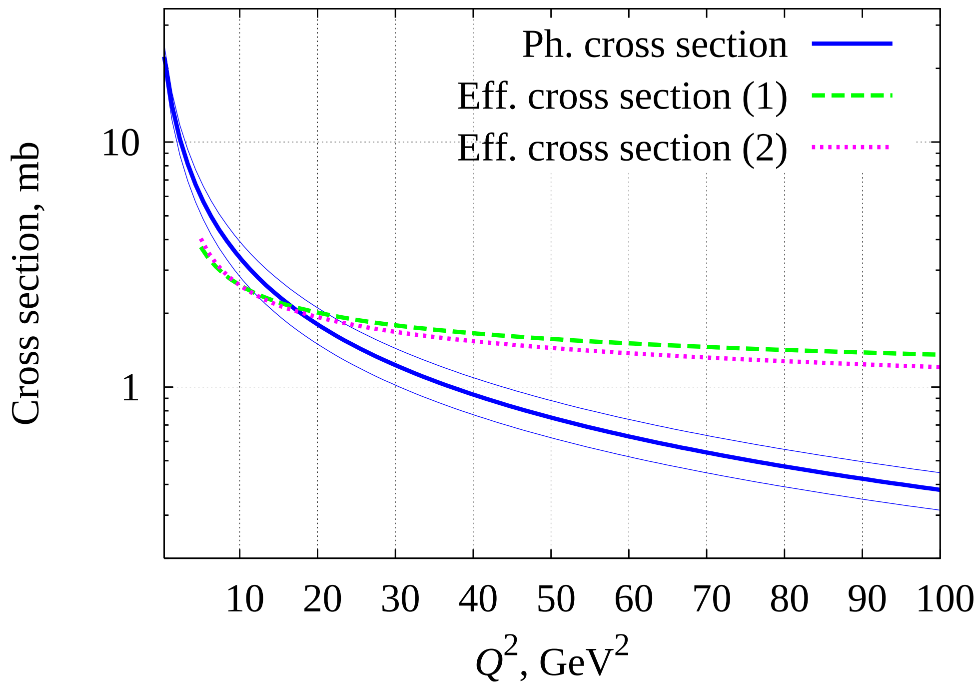
- Parameters from the global fit (all nuclei) are consistent with independent fits to different subsets of nuclei
- The off-shell effect results in the enhancement of the structure function for $x_1 < x < x_0$ and depletion for $x < x_1$ and $x > x_0$.



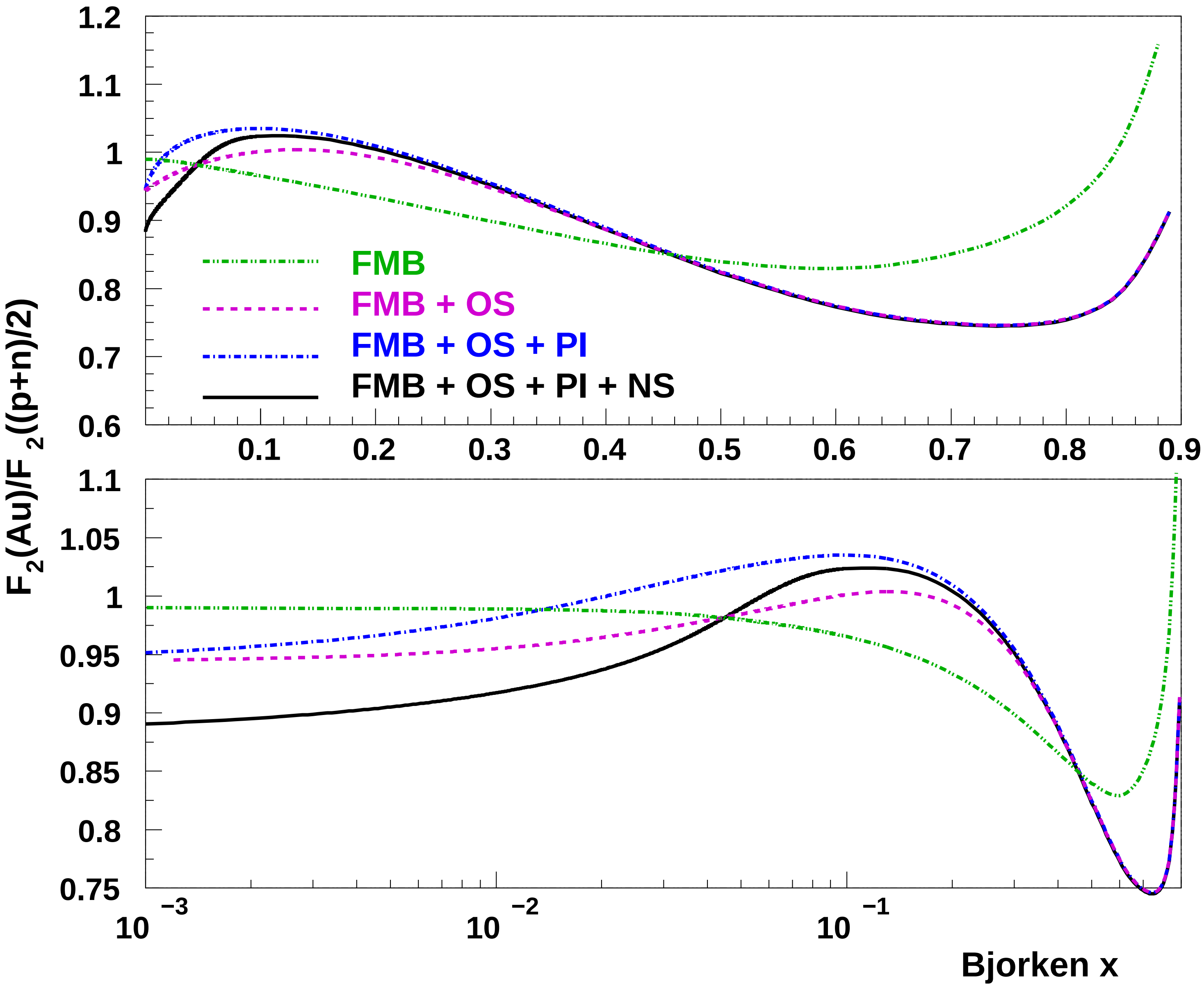
Effective cross section

- The monopole form $\bar{\sigma} = \sigma_0/(1 + Q^2/Q_0^2)$ provides a good fit to existing DIS data on nuclear shadowing for $Q^2 < 20\,\mathrm{GeV}^2$.

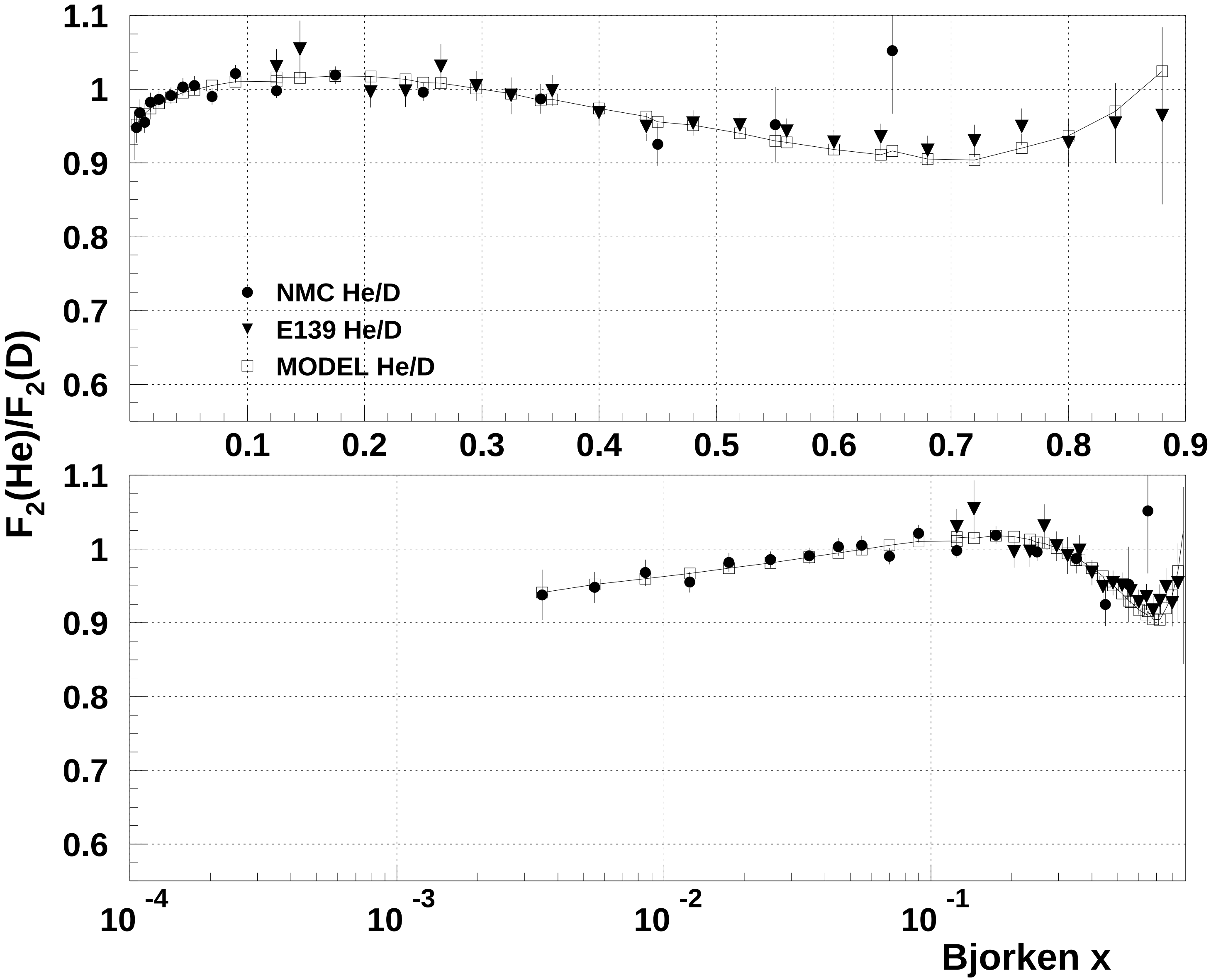
- This does not mean that $\bar{\sigma}$ should vanish as $1/Q^2$ since data are limited to $Q^2 < 20\,\mathrm{GeV}^2$. Effective cross section at high Q^2 can be calculated from the normalization condition of the valence quark distribution $\delta N_{\mathrm{val}}^{\mathrm{off-shell}} + \delta N_{\mathrm{val}}^{\mathrm{shadowing}} = 0$.



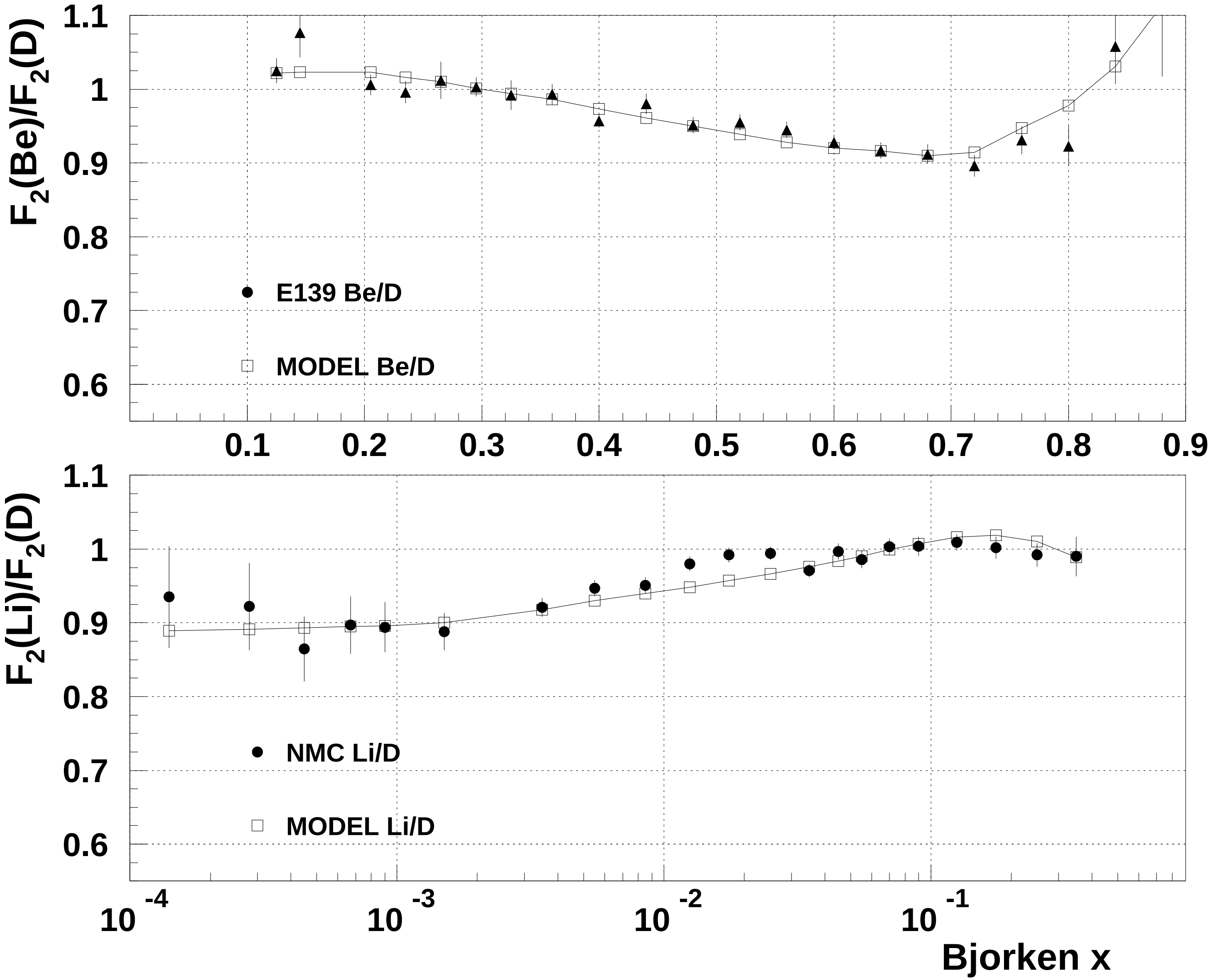
Results for the ratios $\mathcal{R}_2(x, A/B) = F_2^A/F_2^B$



^{4}He/D

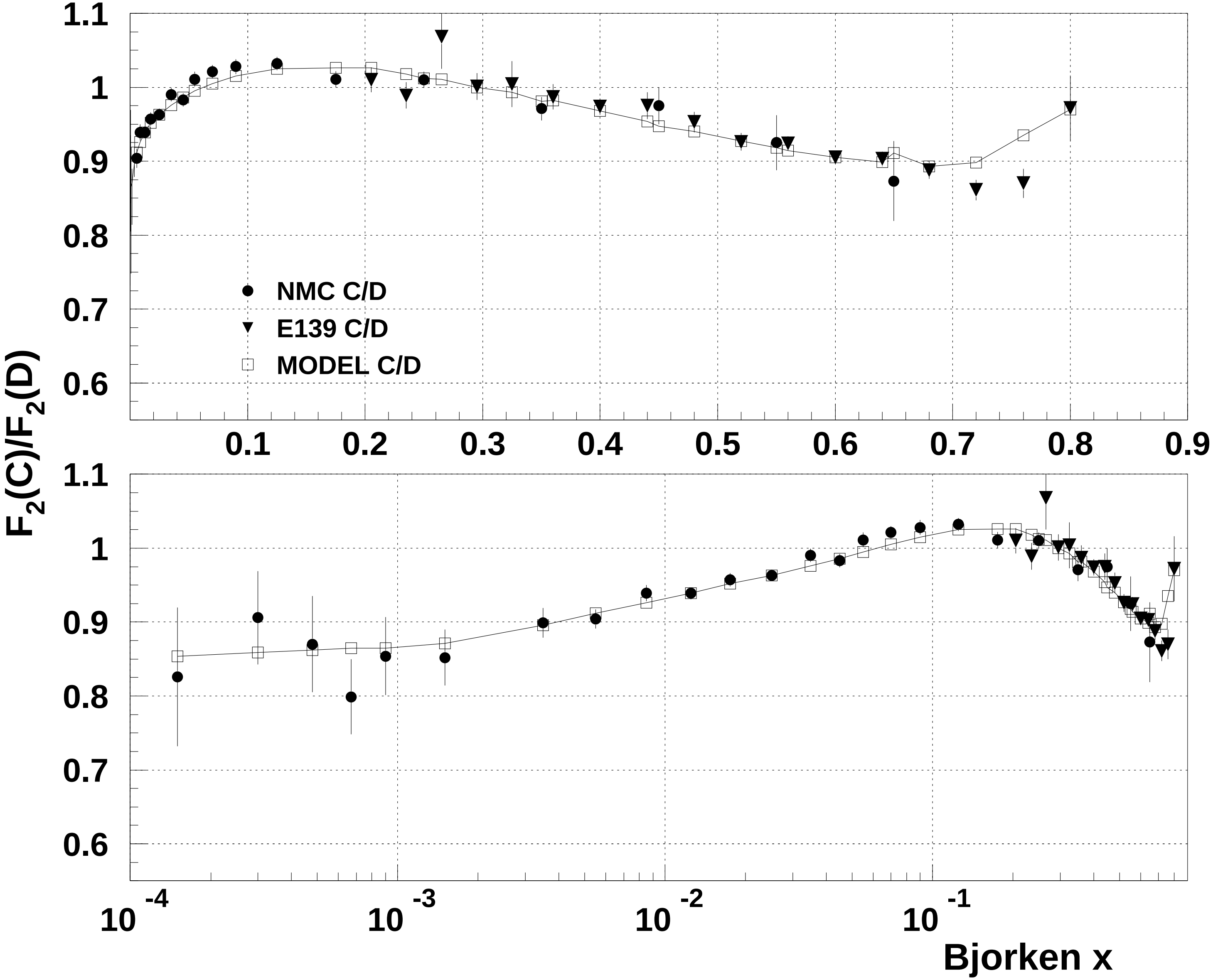

1.1
1
0.9
0.8
0.7
0.6
NMC He/D
E139 He/D
MODEL He/D
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
F2(He)/F2(D)
10 -4
10 -3
10 -2
10 -1
Bjorken x

^{7}Li/D & ^{9}Be/D

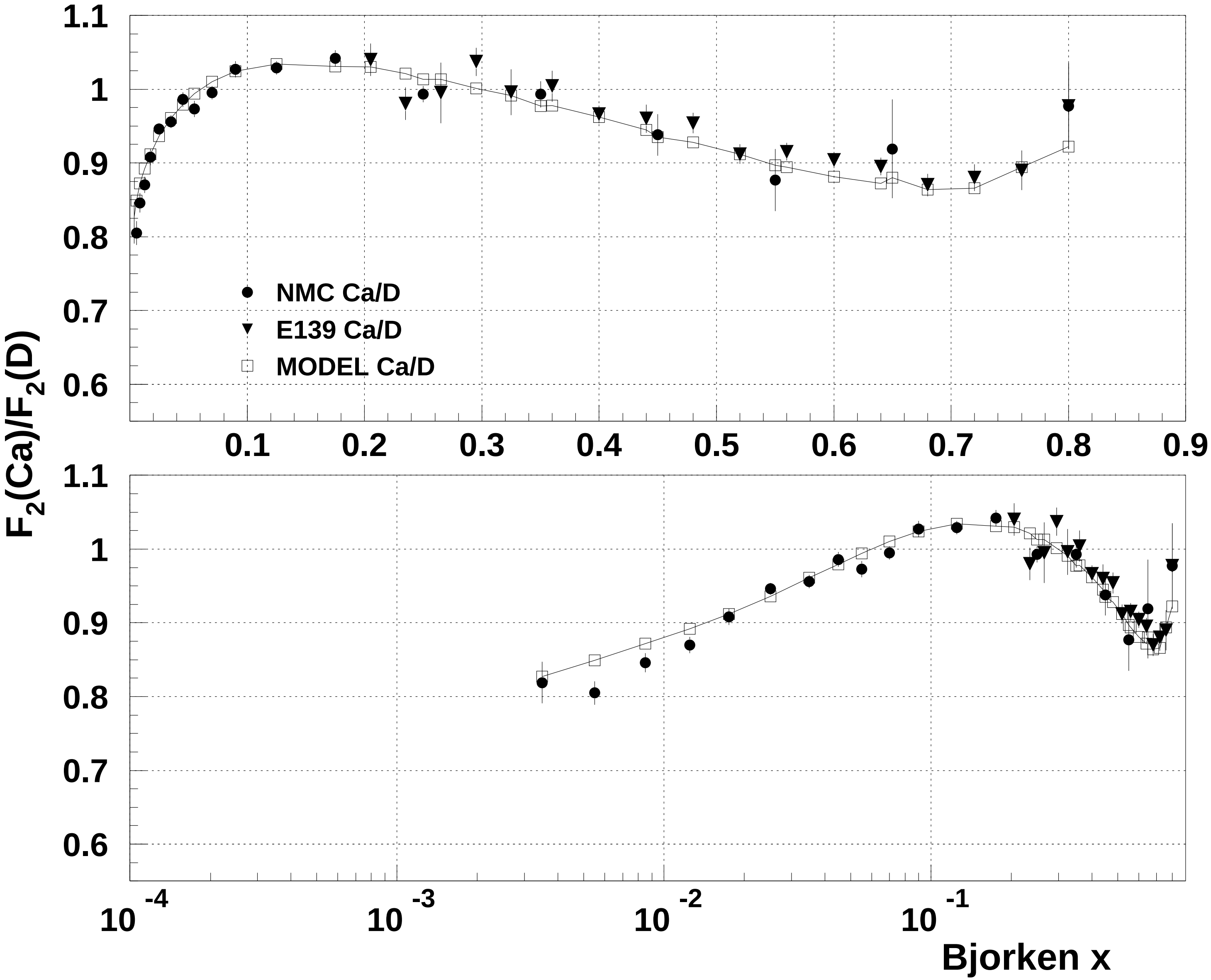


1.1
1
0.9
0.8
0.7
0.6
$F_2(Be)/F_2(D)$
E139 Be/D
MODEL Be/D
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
$F_2(Li)/F_2(D)$
NMC Li/D
MODEL Li/D
10^{-4}
10^{-3}
10^{-2}
10^{-1}
Bjorken x

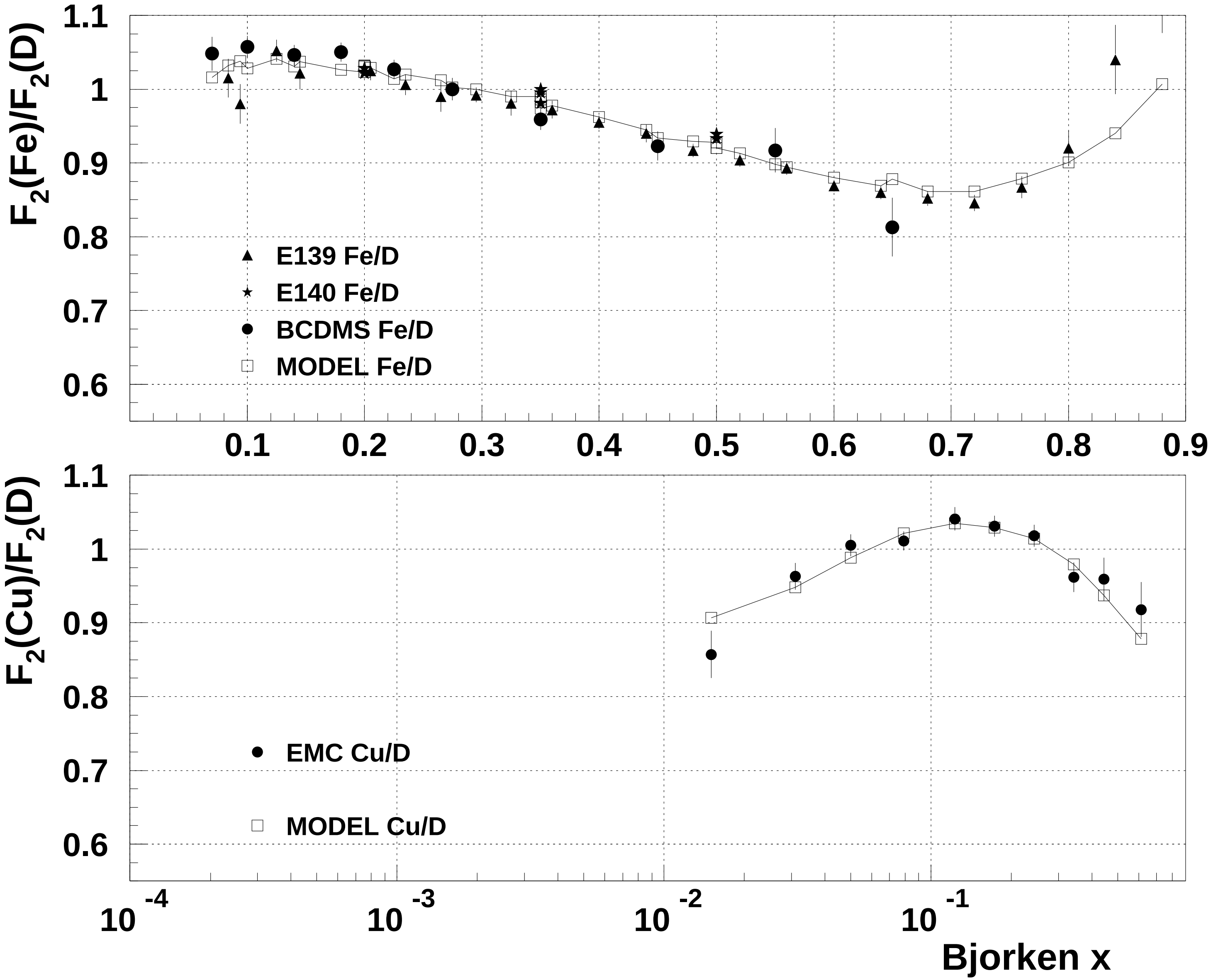
^{12}C/D



^{40}Ca/D

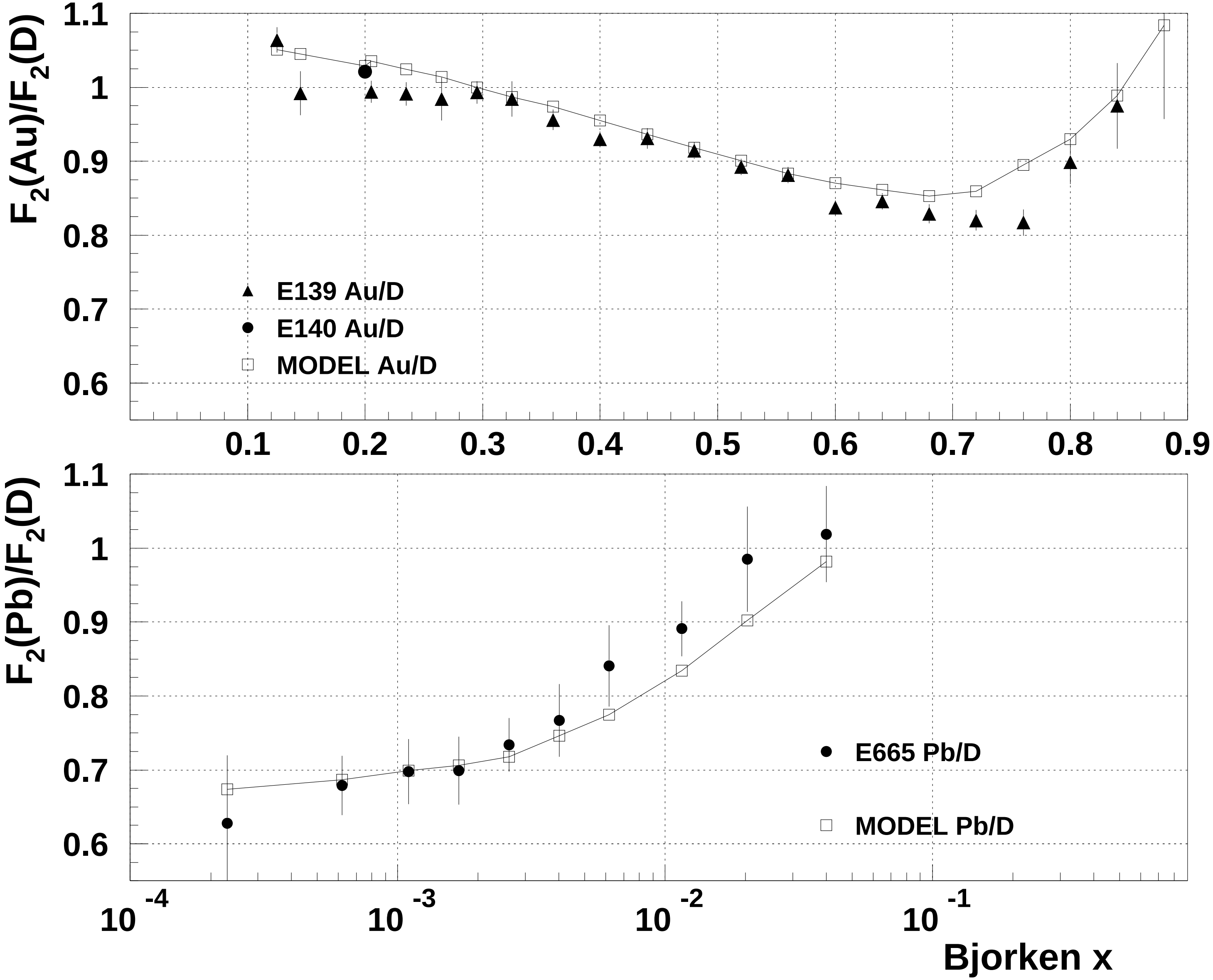


^{56}Fe/D & ^{63}Cu/D

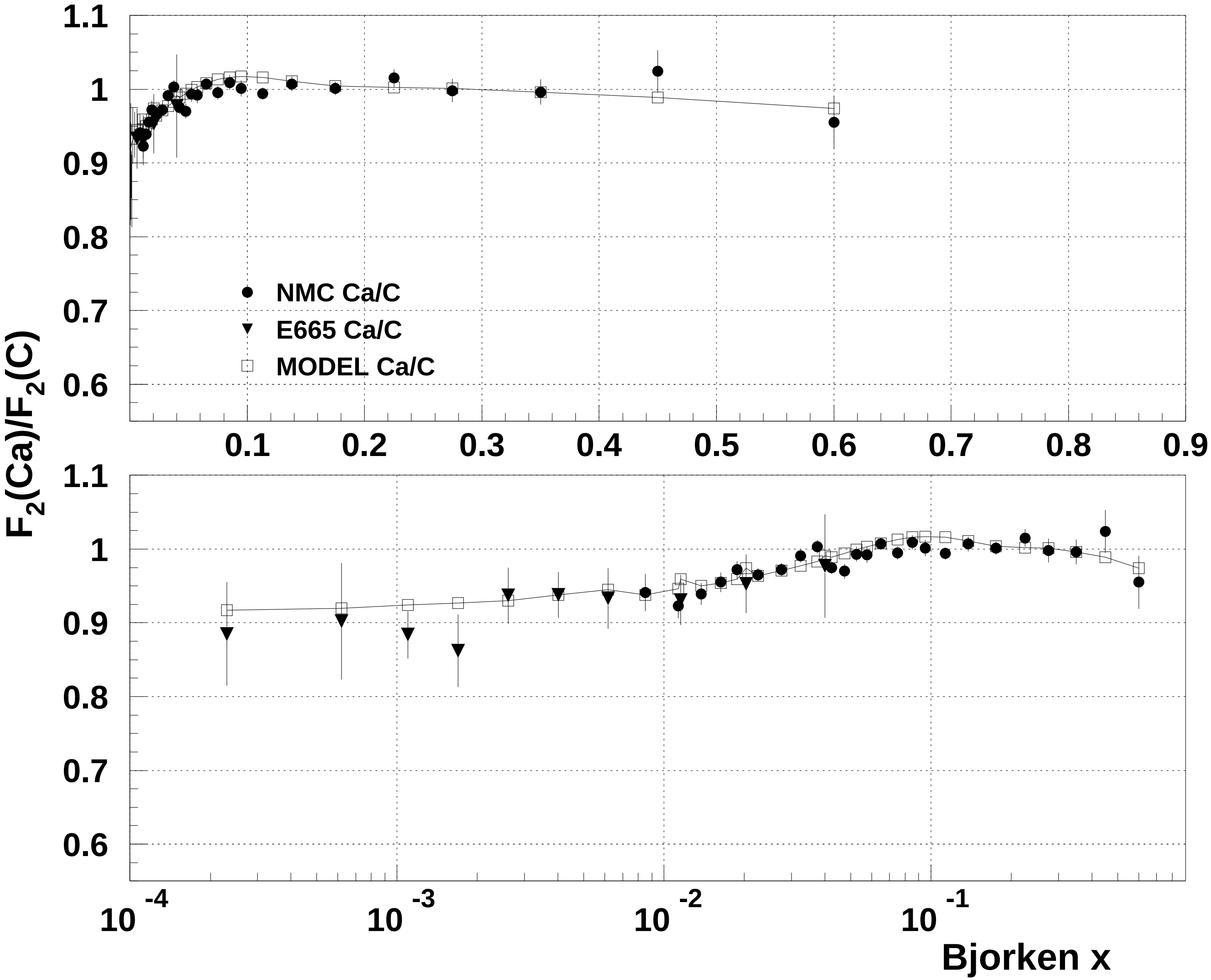


F2(Fe)/F2(D)
1.1
1
0.9
0.8
0.7
0.6
E139 Fe/D
E140 Fe/D
BCDMS Fe/D
MODEL Fe/D
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
F2(Cu)/F2(D)
EMC Cu/D
MODEL Cu/D
10 -4
10 -3
10 -2
10 -1
Bjorken x

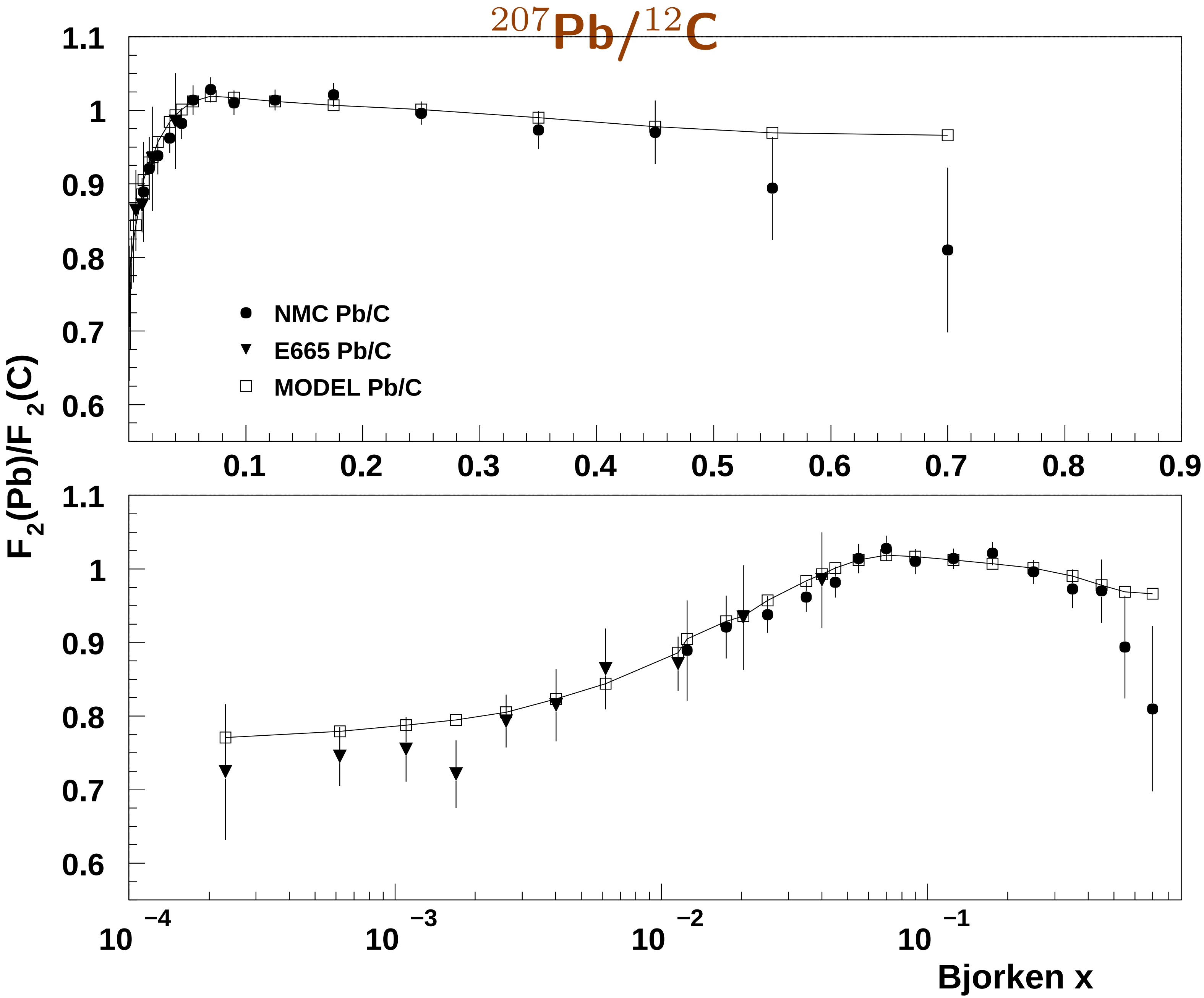
^{197}Au/D & ^{207}Pb/D



^{40}Ca/^{12}C

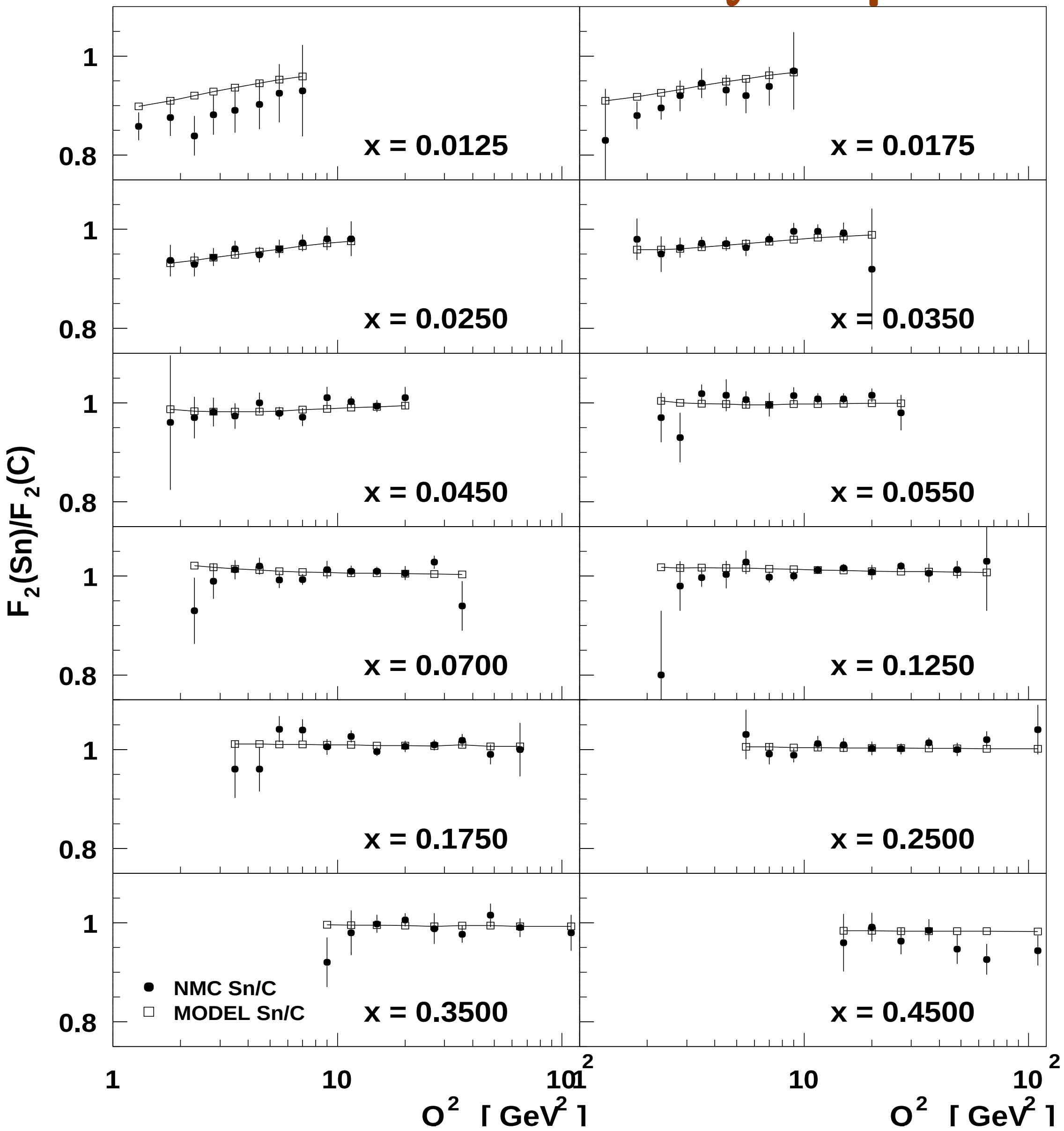


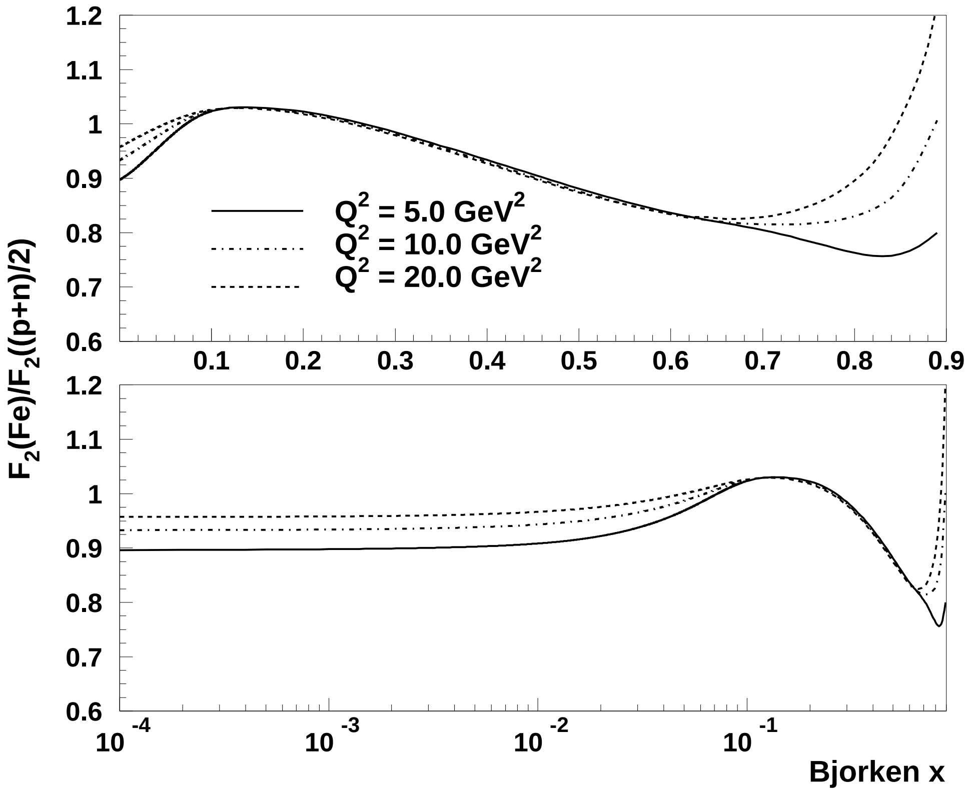
F2(Ca)/F2(C)
1.1
1
0.9
0.8
0.7
0.6
NMC Ca/C
E665 Ca/C
MODEL Ca/C
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
10 -4
10 -3
10 -2
10 -1
Bjorken x



^{207}Pb/^{12}C
F$_2$(Pb)/F$_2$(C)
NMC Pb/C
E665 Pb/C
MODEL Pb/C
Bjorken x

Q^2 dependence of $\mathcal{R}_2$





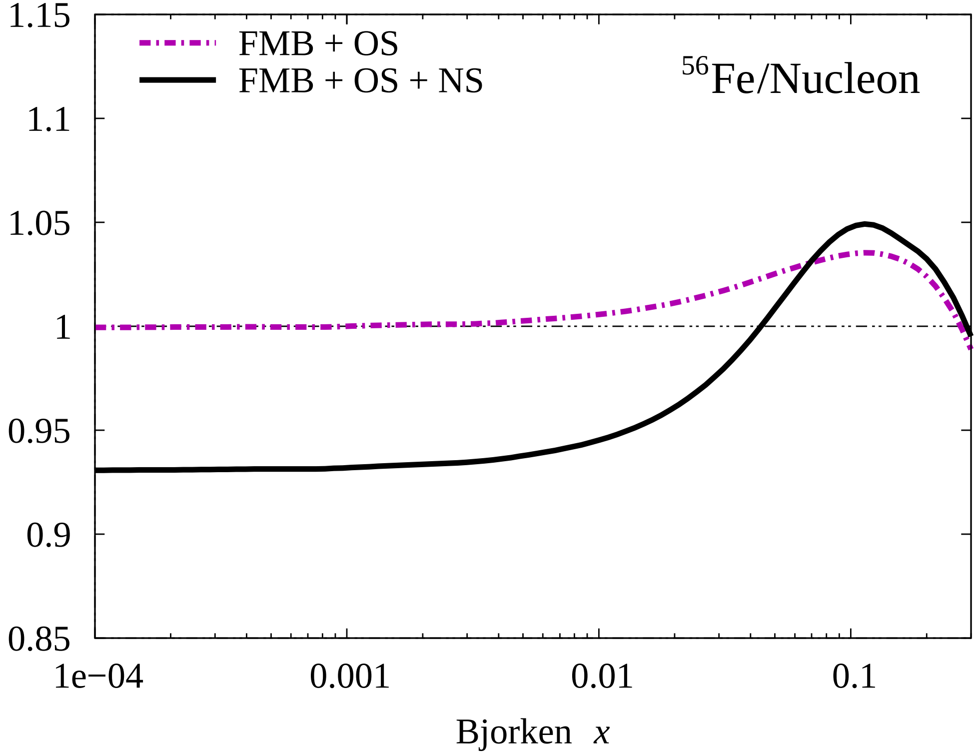
Q^2 dependence of $\mathcal{R}_2$ was observed for $x < 0.05$ (the Q^2 dependence of shadowing effect) and for $x > 0.7$ (the Q^2 dependence of target mass correction)

Nuclear sea and valence quark distributions

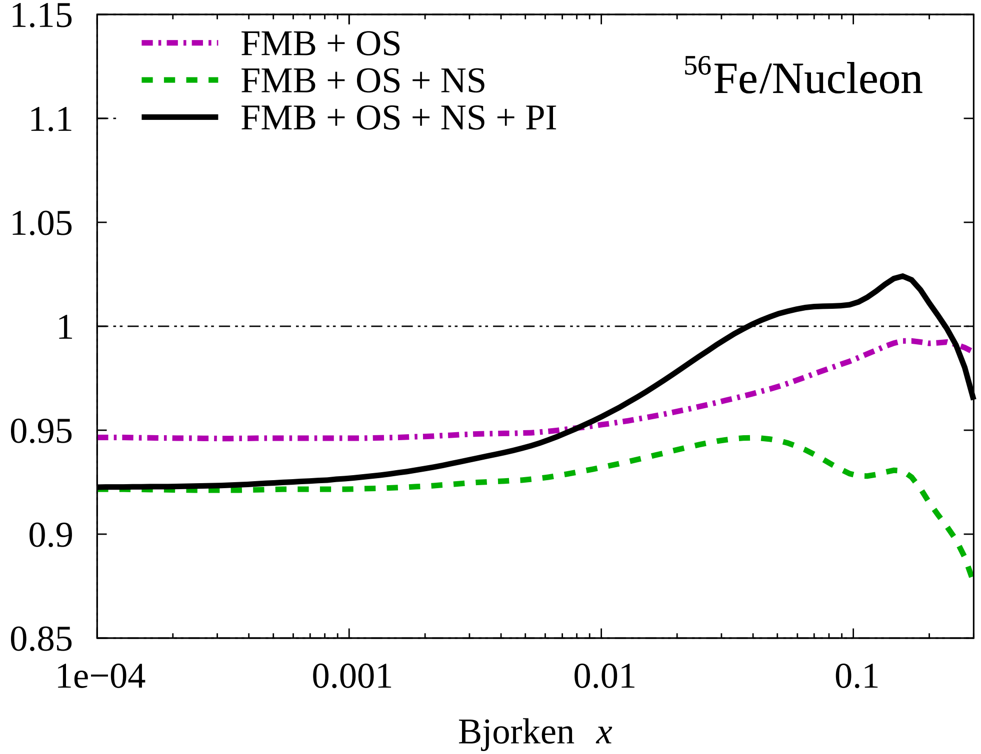
Nuclear corrections for antiquark distribution can be derived from $\delta\mathcal{R}^{(0,-)}$ and $\delta\mathcal{R}^{(0,+)}$:

$$\delta\mathcal{R}_{\rm sea} = \frac{\delta\bar{q}_A}{\bar{q}_N} = \delta\mathcal{R}^{(0,+)} + \frac{q_{\rm val/N}(x)}{2\bar{q}_N(x)}\left(\delta\mathcal{R}^{(0,+)} - \delta\mathcal{R}^{(0,-)}\right)$$

$\delta\mathcal{R}_{\rm val} = \delta\mathcal{R}^{(0,-)}$ at $Q^2 = 20\ \mathrm{GeV}^2$

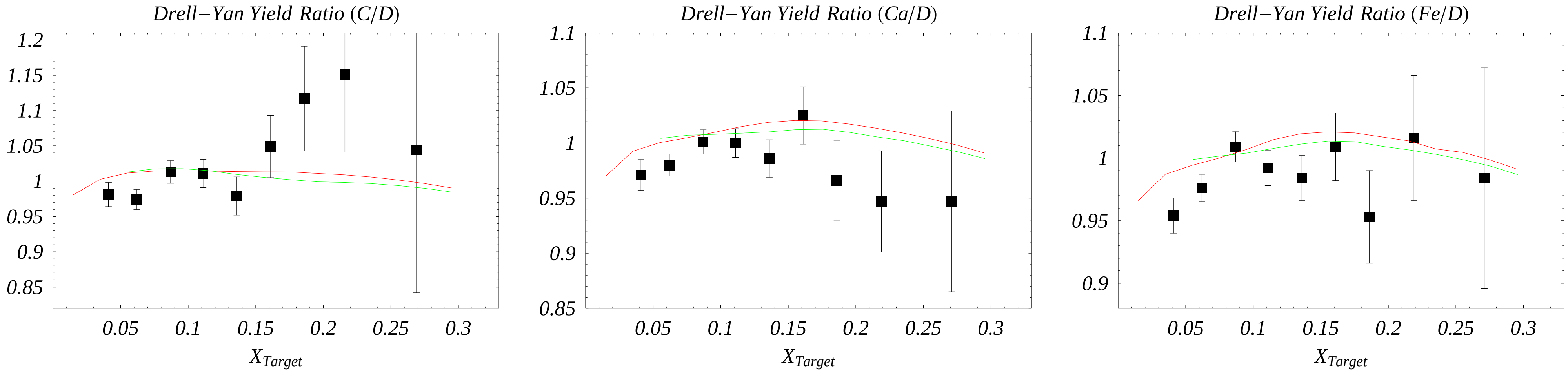


$\delta\mathcal{R}_{\rm sea}$ at $Q^2 = 20\ \mathrm{GeV}^2$



⇒ Note remarkable cancellation between pion and shadowing effects for nuclear antiquark distribution for intermediate region of Bjorken x.

Comparison with Drell-Yan data



Calculations are in reasonable agreement with data on DY ratios (Note that the mass of dimuon pair was not given by E772 and calculation was done for a fixed $Q^2 = 20\ \mathrm{GeV}^2$).

The cancellation from shadowing reconciles nuclear pion excess with DY data.

Summary for the CL DIS analysis

- The model is in a very good agreement with data for the entire kinematical region of x and Q^2 and for all studied nuclei from ^{4}He to ^{207}Pb with overall $\chi^2/\mathrm{d.o.f} = 459/556$ for a 4 parameter fit.

- The fit parameters are common to all nuclei. The parameters are stable for the fits with different subsets of nuclei (see Table 2 of NPA paper).

- The off-shell effect is related to modification of the nucleon structure in nuclear environment. The parameters of $\delta f(x)$ suggest an increase in the size of the bound nucleon valence region (in ^{56}Fe by $\sim 10\%$ on average).

- Not discussed here but worth to mention. Predictions for the deuteron are in a good agreement with E665 D/p data and also with Gomez et.al. extraction of $D/(p+n)$ ratio (except for the region $x > 0.7$).

Nuclear effects in neutrino DIS

- We apply the model developed for charged-lepton nuclear scattering for neutrino-nuclear interactions (for more details see S.K. & R.Petti, PRD46(2007)094023).

- Additional input is required to treat the major nuclear effects for νA scattering.

  $\longrightarrow$ Off-shell corrections for different structure functions (F_2 and F_3) and its dependence on ν and $\bar{\nu}$.

  $\longrightarrow$ Calculation of nuclear shadowing requires the amplitudes $a^{(I,C)}$ for the states with different C-parity (e.g. F_2 and F_3) and isospin I (important for the calculation of the neutron excess correction).

- DIS sum rules for nuclei (Adler and GLS) help to fix unknown amplitudes.

The Adler sum rule (ASR)

$$S_{\rm A} = \int_0^{M_A/M} \mathrm{d}x(F_2^{\bar\nu} - F_2^{\nu})/(2x) = 2I_z$$

- In parton model $S_{\rm A}$ is the difference between number of valence u and d in the target. $S_{\rm A}(p) = +1,\ S_{\rm A}(n) = -1$.

- ASR is independent of Q^2 and survives strong interaction effects because of CVC.

- Nonconservation of axial current is neglected in derivation of ASR. Therefore, ASR is good for sufficiently high Q^2 but violated at low Q^2 (e.g. by PCAC terms).

- For generic nucleus of Z protons and N neutrons $S_{\rm A}/A = \beta = (Z - N)/A$.

Explicit calculation of different nuclear effects:
• FMB correction cancels out. So does the pion correction.
• Both off-shell (OS) and nuclear shadowing (NS) corrections are nonzero. The requirement of exact cancellation between these corrections fixes $\mathrm{Re}\, a^{(1,-)}/\, \mathrm{Im}\, a^{(1,-)}$ and the strength of the NS correction in the isovector $(I = 1, C = -1)$ channel.

Gross–Llewellyn-Smith sum rule (GLS)

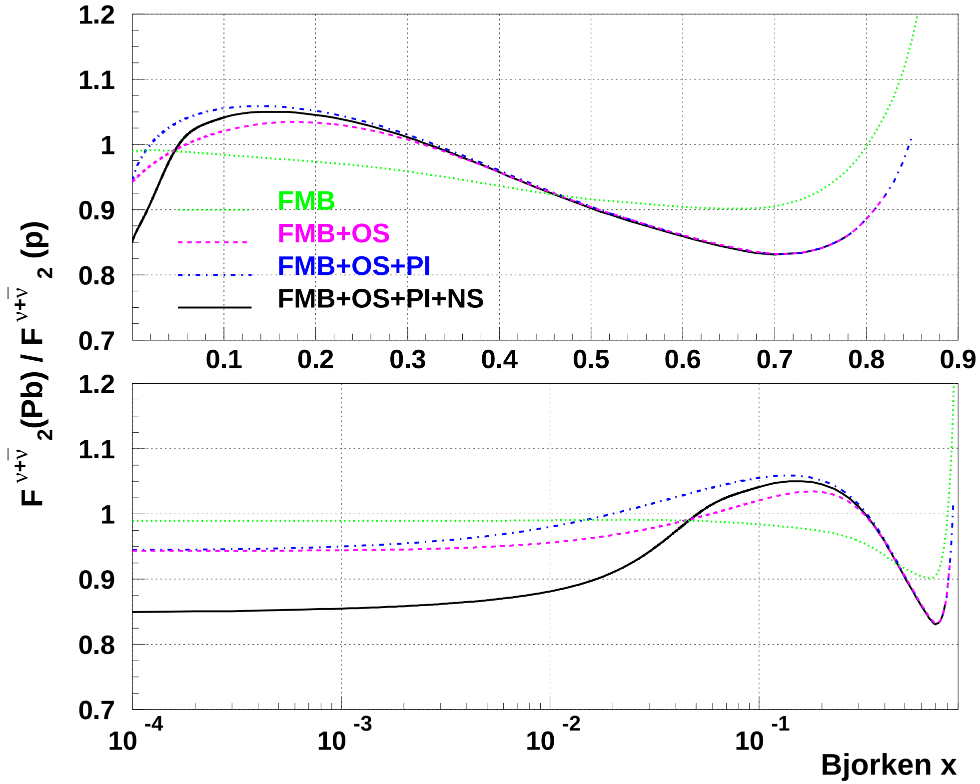
$$S_{\mathrm{GLS}} = \frac{1}{2}\int_0^{M_A/M} \mathrm{d}x (F_3^{\bar\nu} + F_3^{\nu})$$

- In parton model $S_{\mathrm{GLS}} = 3$ is the number of valence u and d quarks in the target.

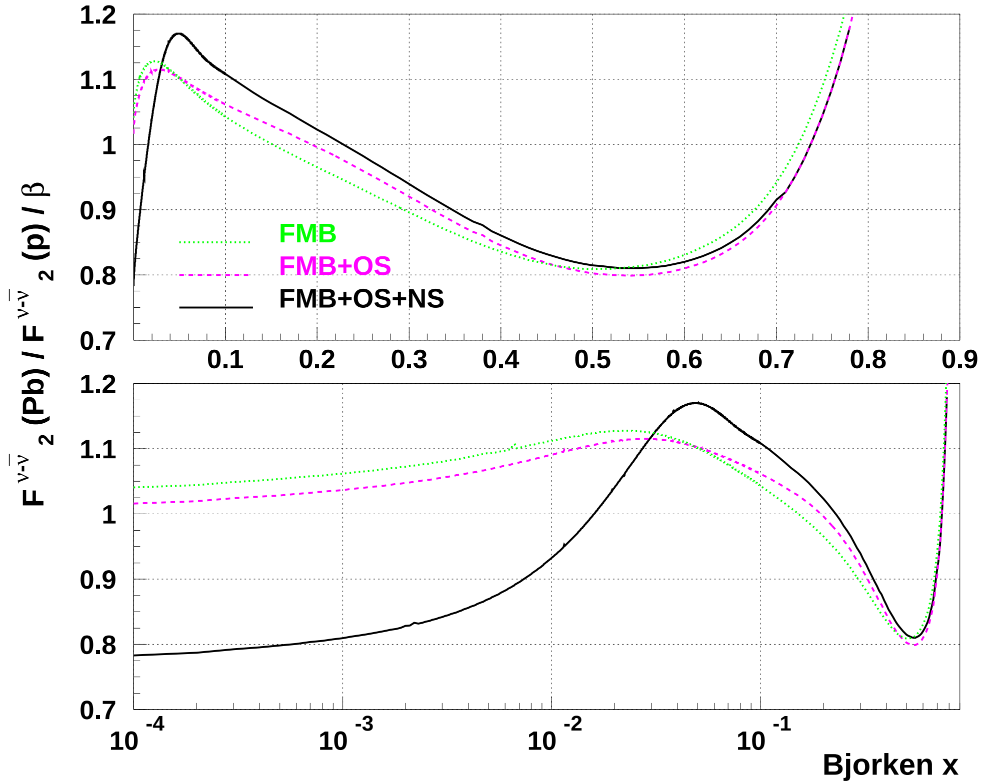
- In QCD the relation between S_{GLS} and the baryon number only holds at asymptotic Q^2. S_{GLS} is affected by QCD radiative corrections and HT effects $S_{\mathrm{GLS}} = 3(1 - \alpha_S/\pi - 3.25(\alpha_S/\pi)^2 + \cdots) + \mathrm{HT}_{\mathrm{GLS}}$.

Explicit calculation of different nuclear effects:
• FMB correction to S_{GLS} cancels out. Nuclear pion correction to $F_3^{\nu+\bar\nu}$ vanishes.
• Both off-shell (OS) and nuclear shadowing (NS) corrections are nonzero. The requirement of exact cancellation between these corrections fixes $\mathrm{Re}\, a^{(0,-)}/\,\mathrm{Im}\, a^{(0,-)}$ and the strength of the NS correction in the isoscalar $(I = 0, C = -1)$ channel.

Dependence of Nuclear Effects on C-parity

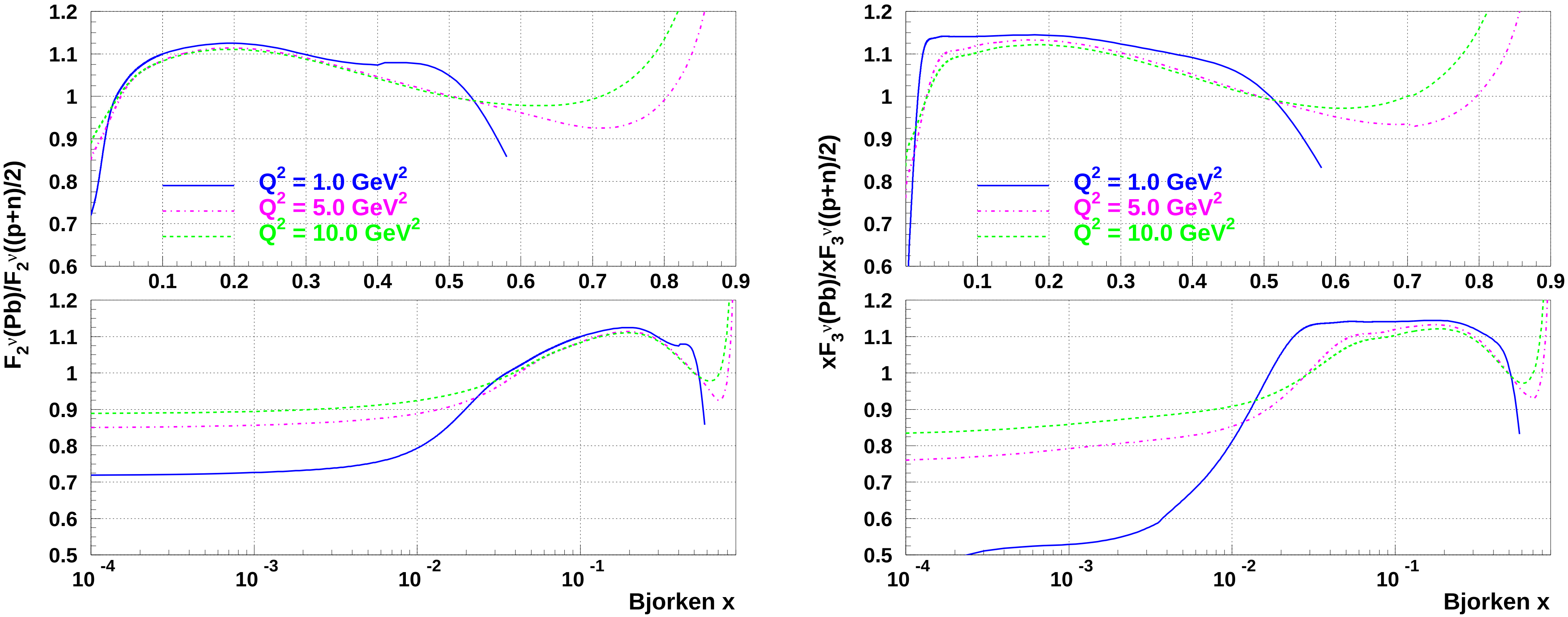


The ratio $\frac{1}{A}F_2^{(\nu+\bar{\nu})A}/F_2^{(\nu+\bar{\nu})p}$ calculated for ^{207}Pb at $Q^2 = 5\ \mathrm{GeV}^2$. The labels on the curves correspond to effects due to Fermi motion and nuclear binding (FMB), off-shell correction (OS), nuclear pion excess (PI) and coherent nuclear processes (NS).



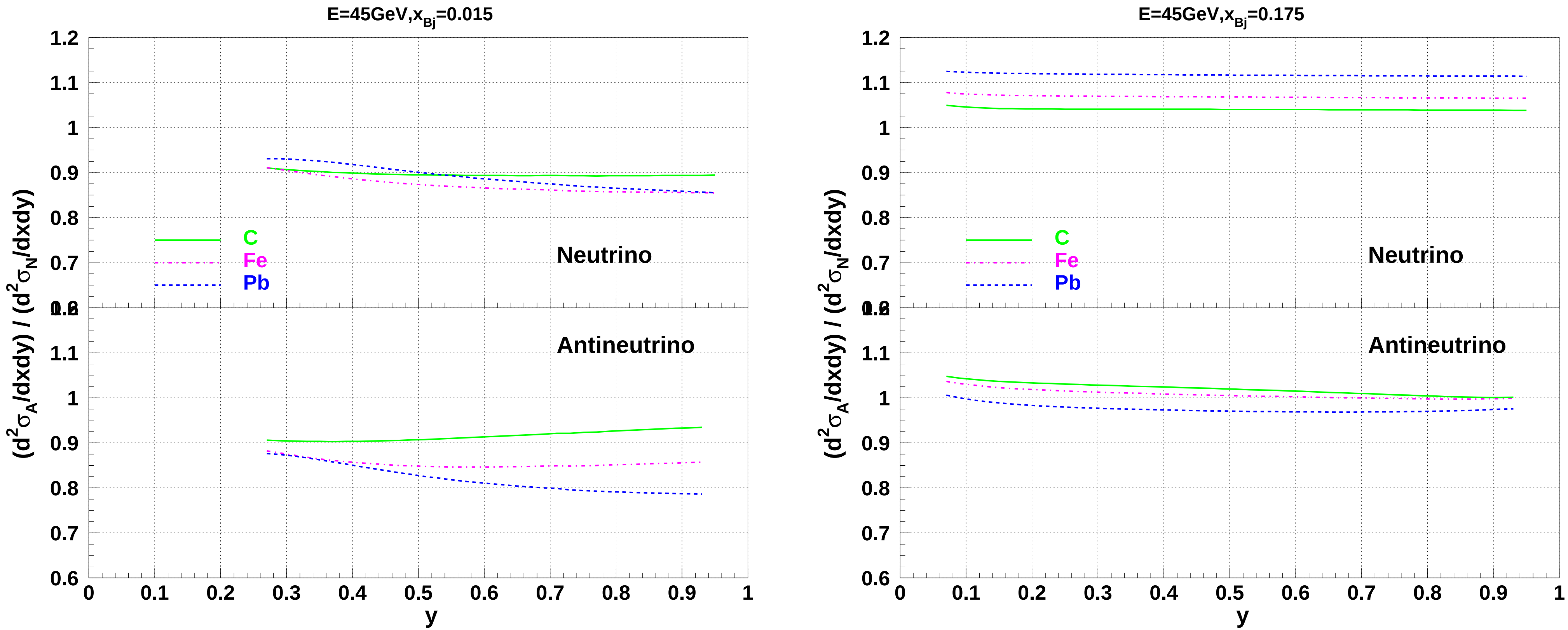
The ratio $\frac{1}{A}F_2^{(\nu-\bar{\nu})A}/(\beta F_2^{(\nu-\bar{\nu})p})$ calculated for ^{207}Pb at $Q^2 = 5\,\mathrm{GeV}^2$. The labels on the curves correspond to effects due to Fermi motion and nuclear binding (FMB), off-shell correction (OS) and coherent nuclear processes (NS).

Nuclear Effects for F_2^ν and F_3^ν

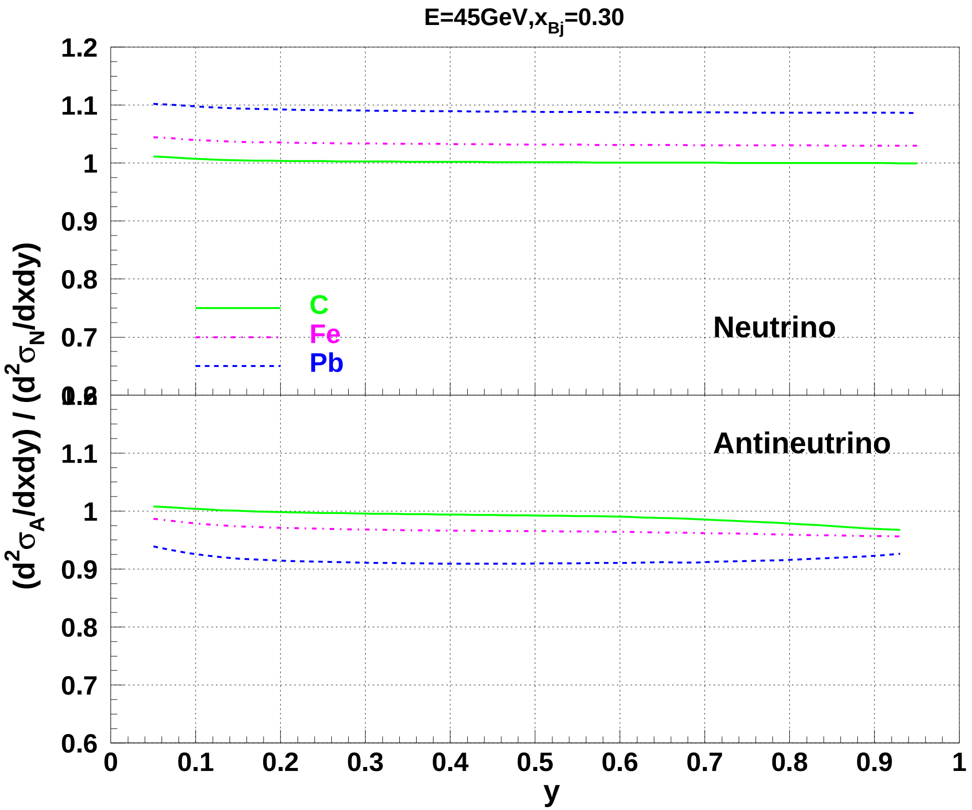


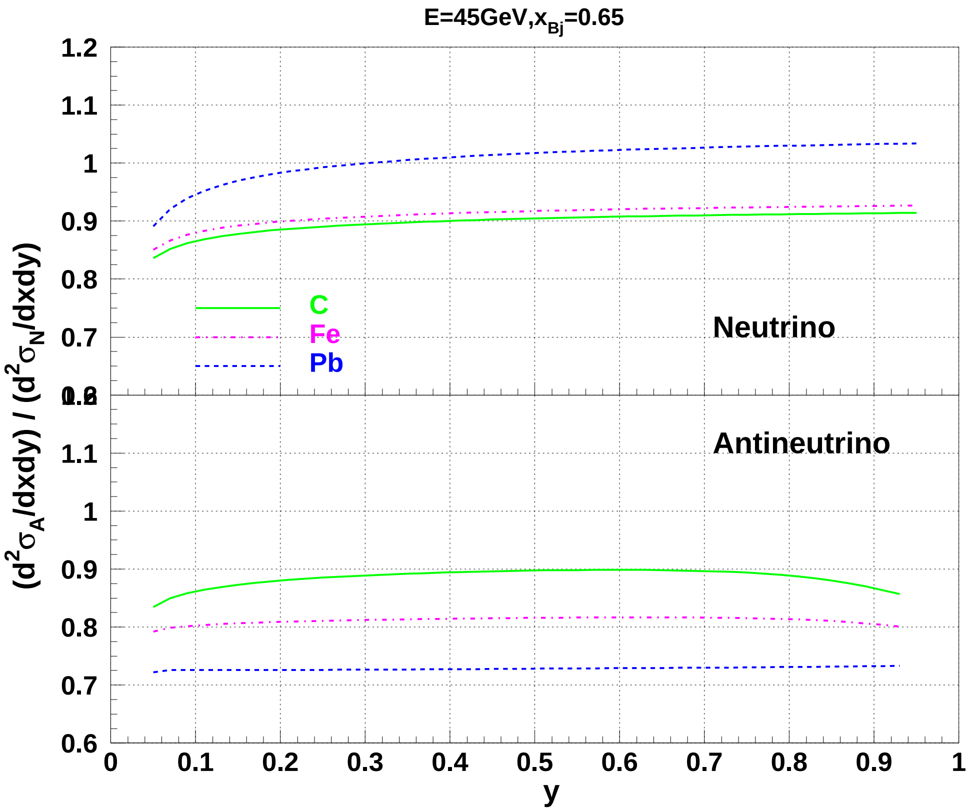
The ratios of CC neutrino structure functions for ^{207}Pb normalized to one nucleon and those of the isoscalar nucleon (p+n)/2 (left panel for F_2 and right panel for xF_3).

(Anti)neutrino cross sections



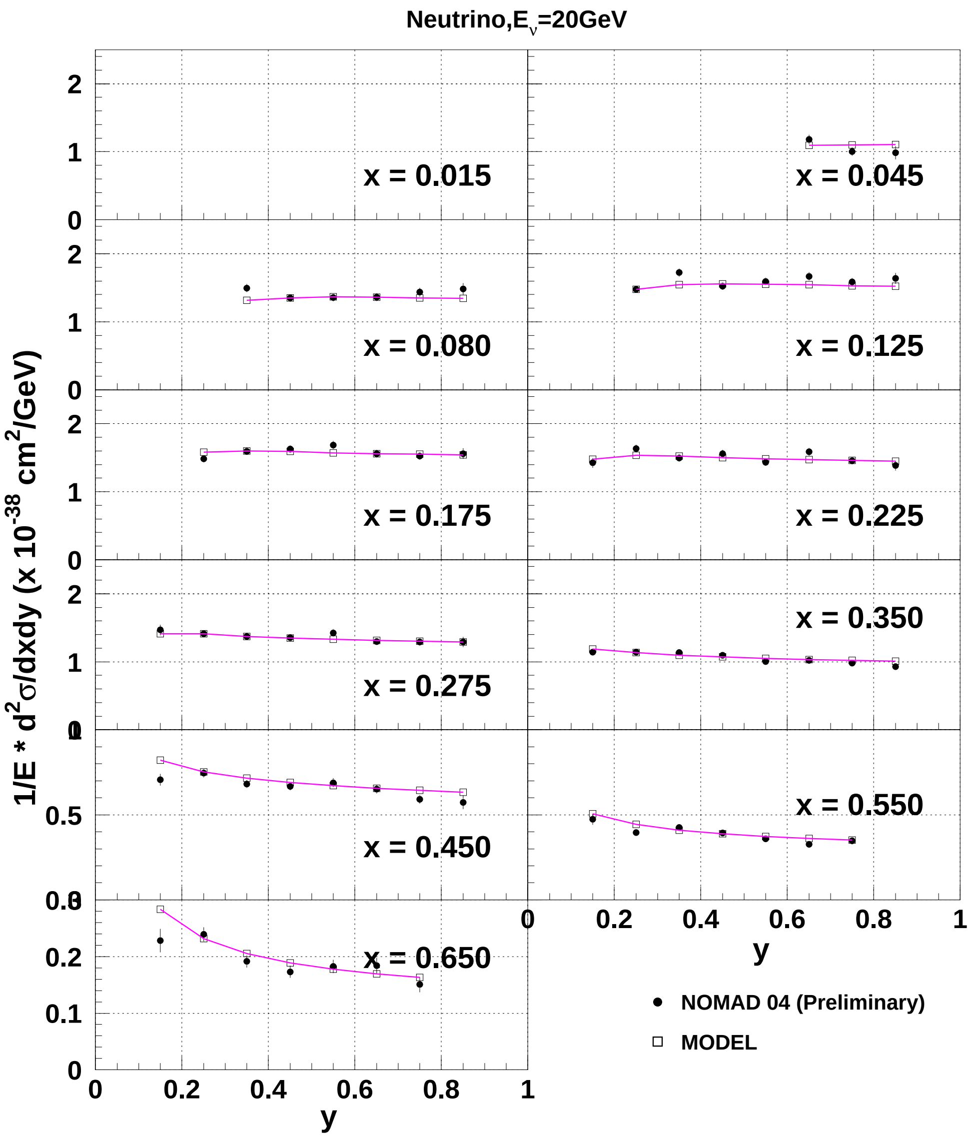
Note the cancellation of nuclear effects for antineutrino at $x \sim 0.1 \div 0.2$. Antineutrino cross section is not very sensetive to the target material in this region.

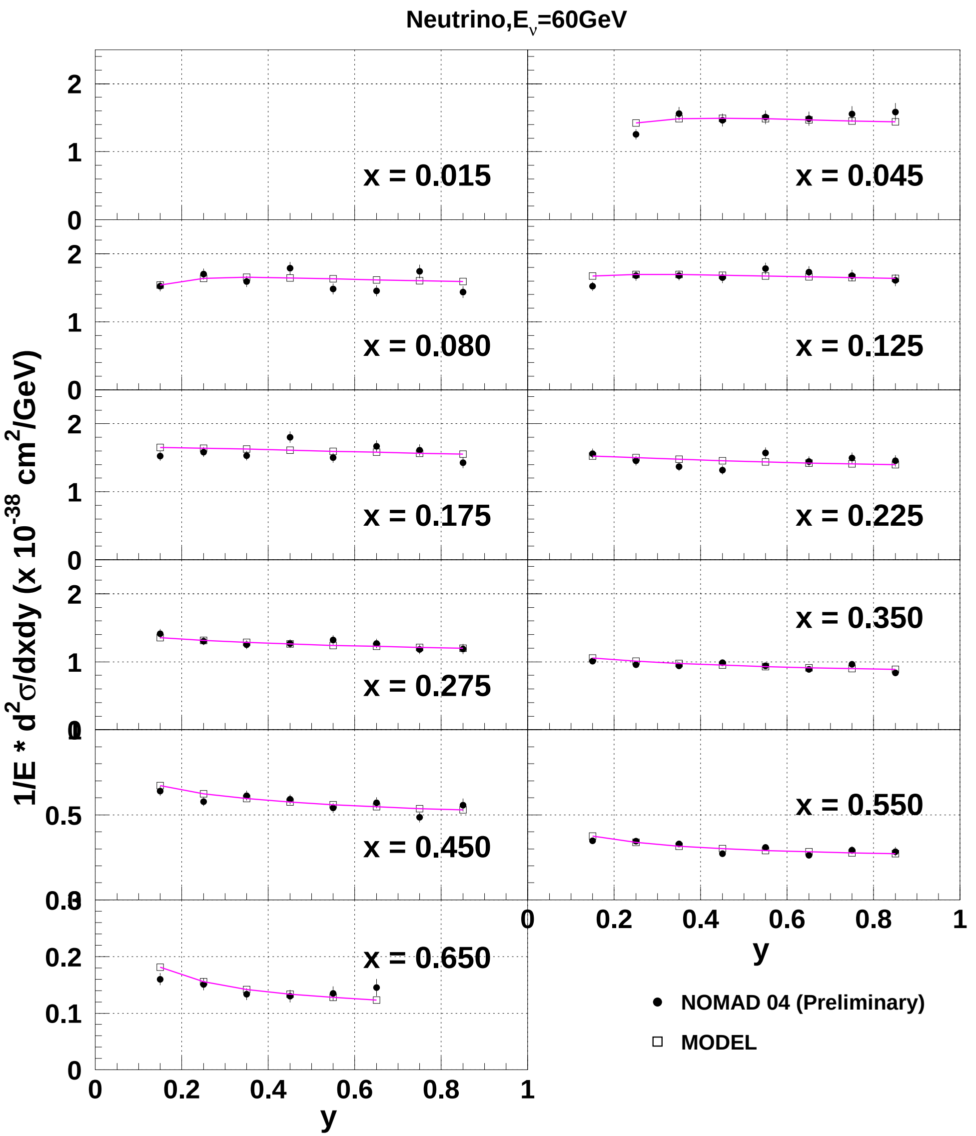




Note the cancellation of nuclear effects at $x \sim 0.3$ for the isoscalar target (^{12}C). Nuclear effects in this region are driven by the neutron excess.

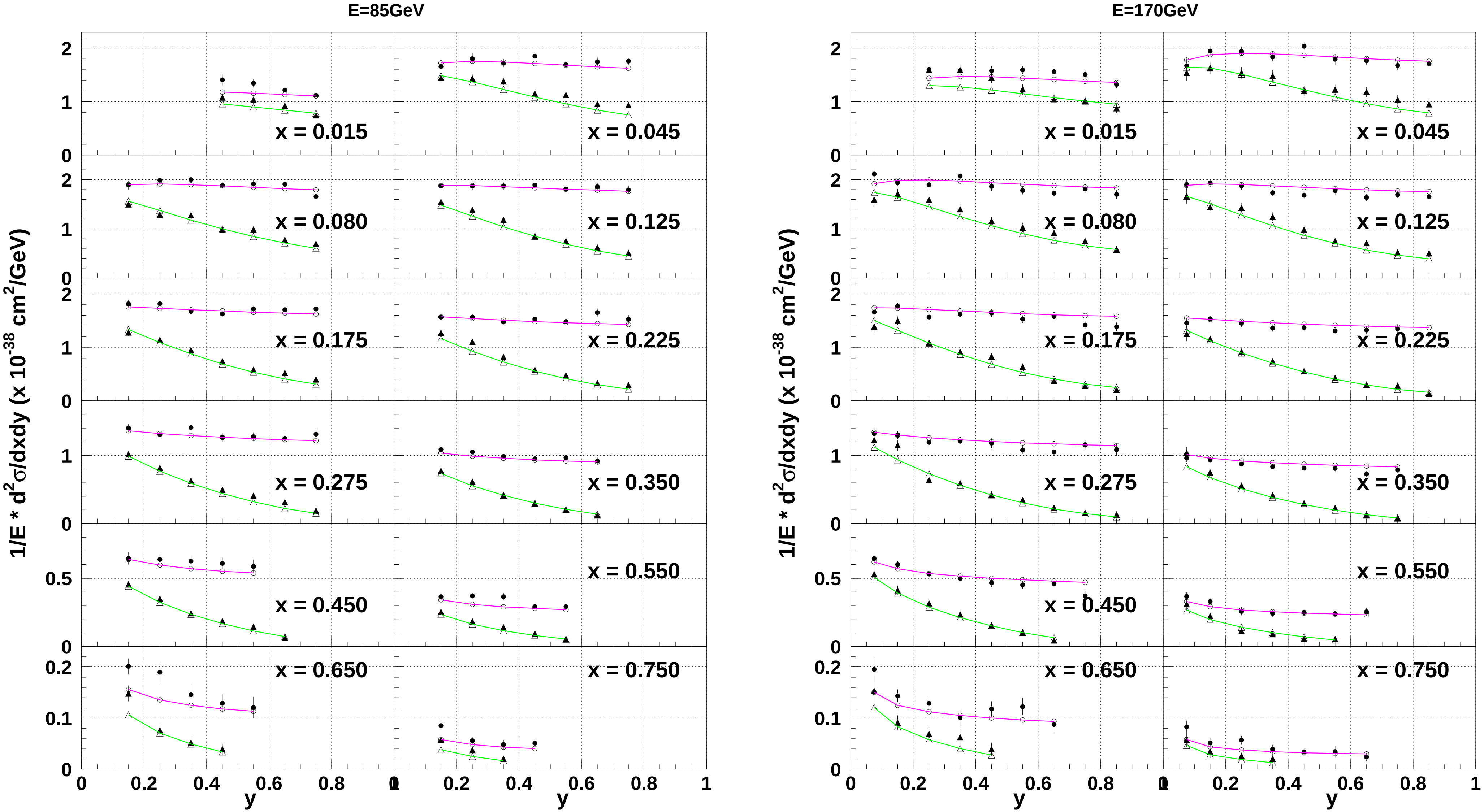
Comparison with NOMAD νC cross sections





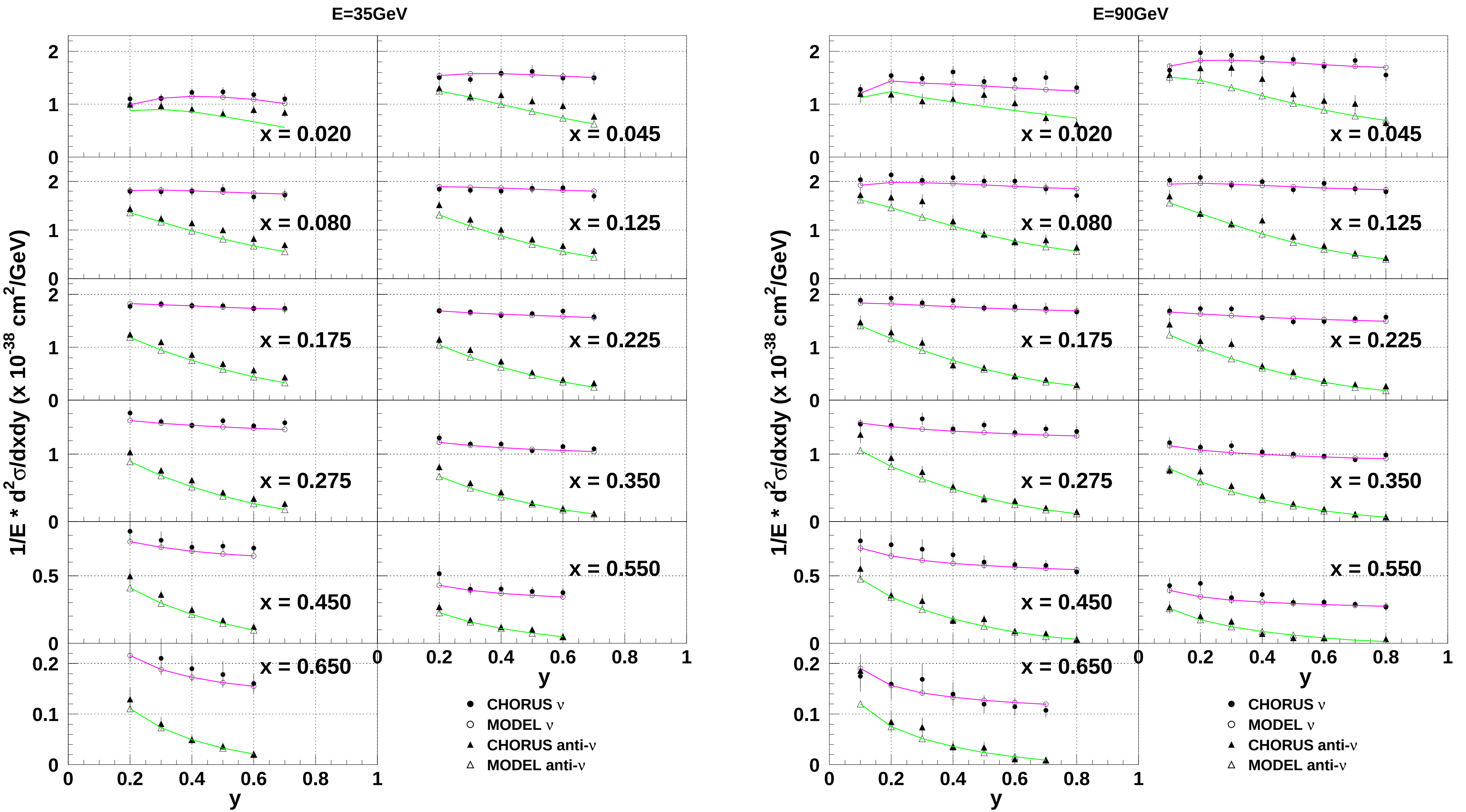
Data: R. Petti hep-ex/0602022

Comparison with NuTeV $\nu(\overline{\nu})$Fe cross sections



Data: M. Tzanov et.al. hep-ex/0507040

Comparison with CHORUS $\nu(\overline{\nu})$Pb cross sections



Data: CHORUS Collab. PLB632(2006)65

Summary

- A detailed quantitative study of nuclear EMC effect was performed in a wide kinematical region of x and Q^2 and for nuclei from ^{4}He to ^{207}Pb. A model was developed which takes into account the QCD treatment of the nucleon structure functions and addresses a number of nuclear effects including nuclear shadowing, Fermi motion and nuclear binding, nuclear pions and off-shell corrections to bound nucleon structure functions.

- The approach was applied to calculate neutrino-nuclear DIS structure functions and cross sections. We discussed in detail how the nuclear effects depend on the structure function type and C-parity.

- Our predictions for (anti)neutrino inelastic differential cross sections agree well with recent data on ^{12}C (NOMAD), ^{56}Fe (NuTeV), ^{207}Pb (CHORUS).